NASA CARBON MONITORING SYSTEM (CMS)

MULTI-STATE WORKING GROUP QUARTERLY MEETING

Meeting Focus: "Scaling Up the High Resolution Carbon Monitoring and Modeling Products to the Northeast U.S.: Discussion of Climate Action Plans, Current Carbon Monitoring Strategy, and Carbon Monitoring Needs and Interests for Stakeholders in the States of New Hampshire, and Maine"

Edil Sepulveda Carlo, NASA Goddard Space Flight Center

Friday, February 7, 2020

Meeting Goals & Discussion Topics

- Discuss Science Team progress, plans, and timelines for developing the following products for the NE states:
  - 30m aboveground biomass maps with uncertainty
  - 0.5 and 1m canopy cover maps
  - 1m canopy height maps
  - 90m ecosystem modeling-based maps of carbon sequestration potential
- Learn about the uses and applications of CMS data products for state officials in Maryland and for the USFS
- Learn about upcoming Regional Workshop on Integrating Technical Assistance with Policy Action
- Provide stakeholders with the opportunity to discuss data needs, challenges, and interests, as well as updates of policies, programs, and initiatives that could benefit from CMS carbon data products
- **Understand climate change action plans, mandates, and GHG reduction goals in geographic area of work**
- Discuss further lessons learned on potential applications of carbon products, identify common needs and solutions, and make progress in incorporating science into policy and decision making
- Identify action items and next steps & plan for future workshop and meetings

More information: http://carbonmonitoring.umd.edu

Multi State Working Group Webpage: https://carbon.nasa.gov/multistate_wg

To Download MD data: http://dx.doi.org/10.3334/ORNLDAAC/1320

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Stakeholder Feedback – Discussion Questions

- What are the major policy drivers for climate change mitigation at the state level?
  - Policy and decision making timelines that we should be aware of
- What is your current source of data? Spatial resolution?
- What are some data gaps and challenges in your work?
- What scientific advancement(s) could contribute to your work?
  - What data do you need? When? Be as specific as possible.
- How can we help you? Identify next steps.

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Multi-State Working Group Next Steps

- Multi-State Working Group Webpage Updates
  - Science Information: Links to Data, Metadata
  - Quarterly Meetings: Agenda, Presentations, Recording, Report
  - List of Upcoming Events
    - Regional Workshop
    - Multi-State WG Quarterly Meetings
    - Joint USFS-NASA Applications Workshop
    - CMS Science Team Meeting & Applications Workshop
    - Other NASA Carbon-related Meetings
- Regional Workshop on Integrating Technical Assistance with Policy Action
  - March 12-13, The Hotel at the University of Maryland
- Value of CMS Data Products & Data Needs Survey for NE States – Summer 2020

For Questions or to be included in the WG Mailing List:

Email Contact: edil.sepulvedacarlo@nasa.gov

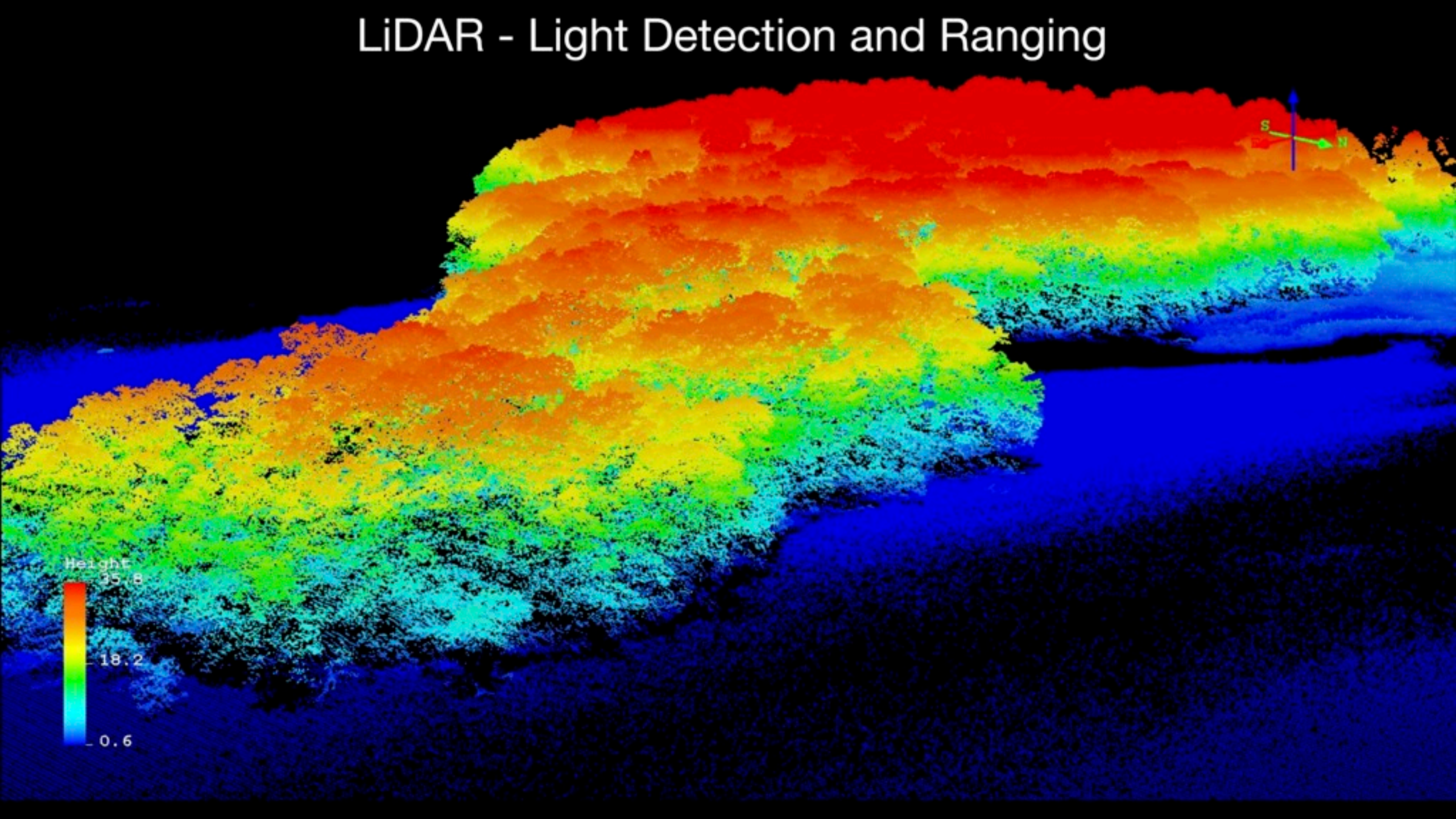
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Carbon Monitoring System

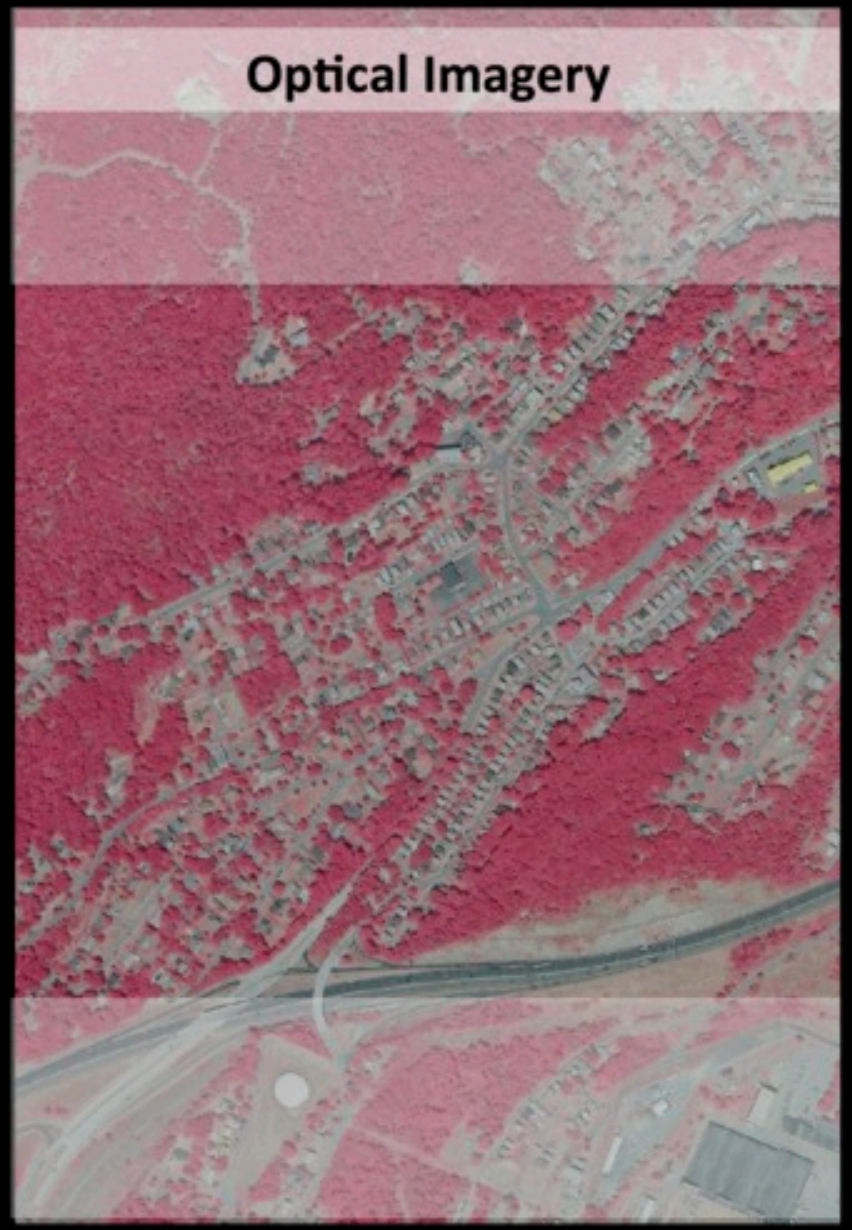
The goal for NASA's CMS project is to prototype the development of capabilities necessary to support stakeholder needs for Monitoring, Reporting, and Verification (MRV) of carbon stocks and fluxes.

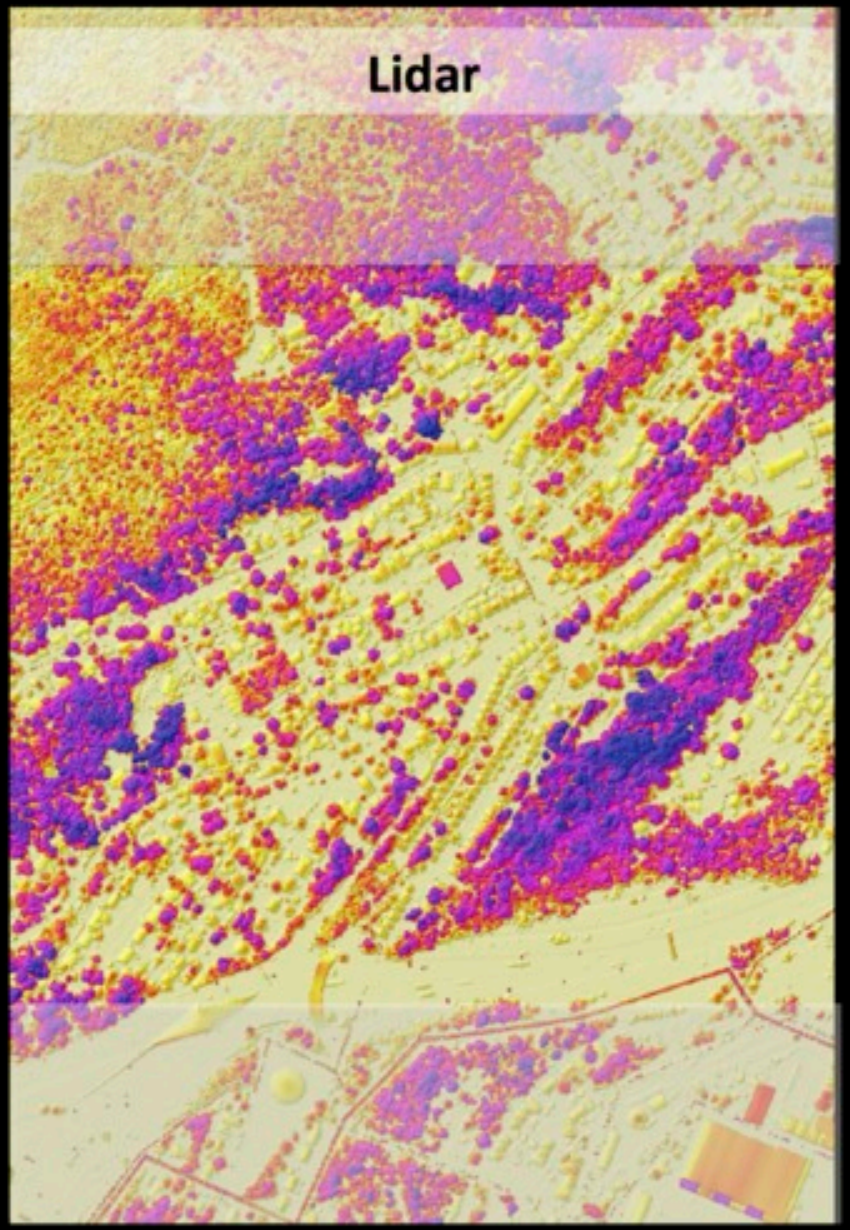
High resolution carbon monitoring and modeling prototype

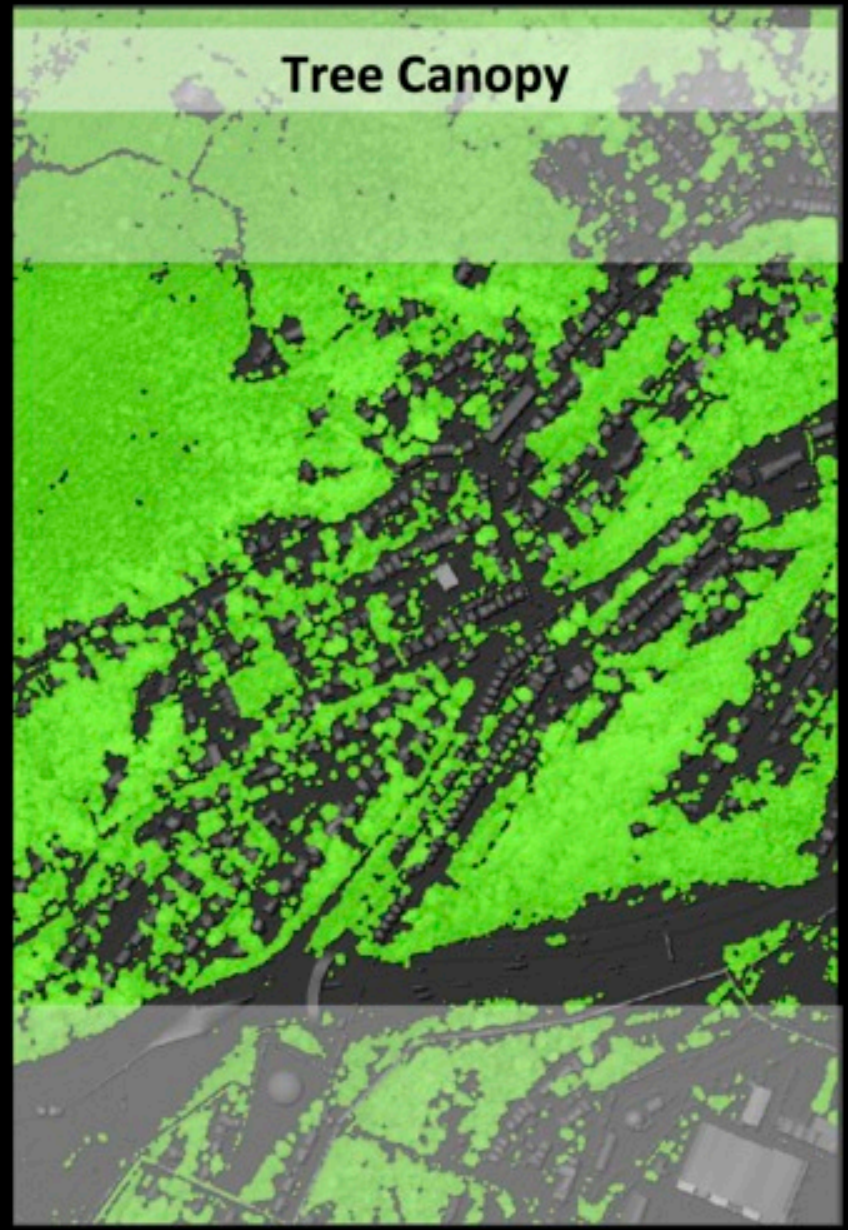
LiDAR - Light Detection and Ranging

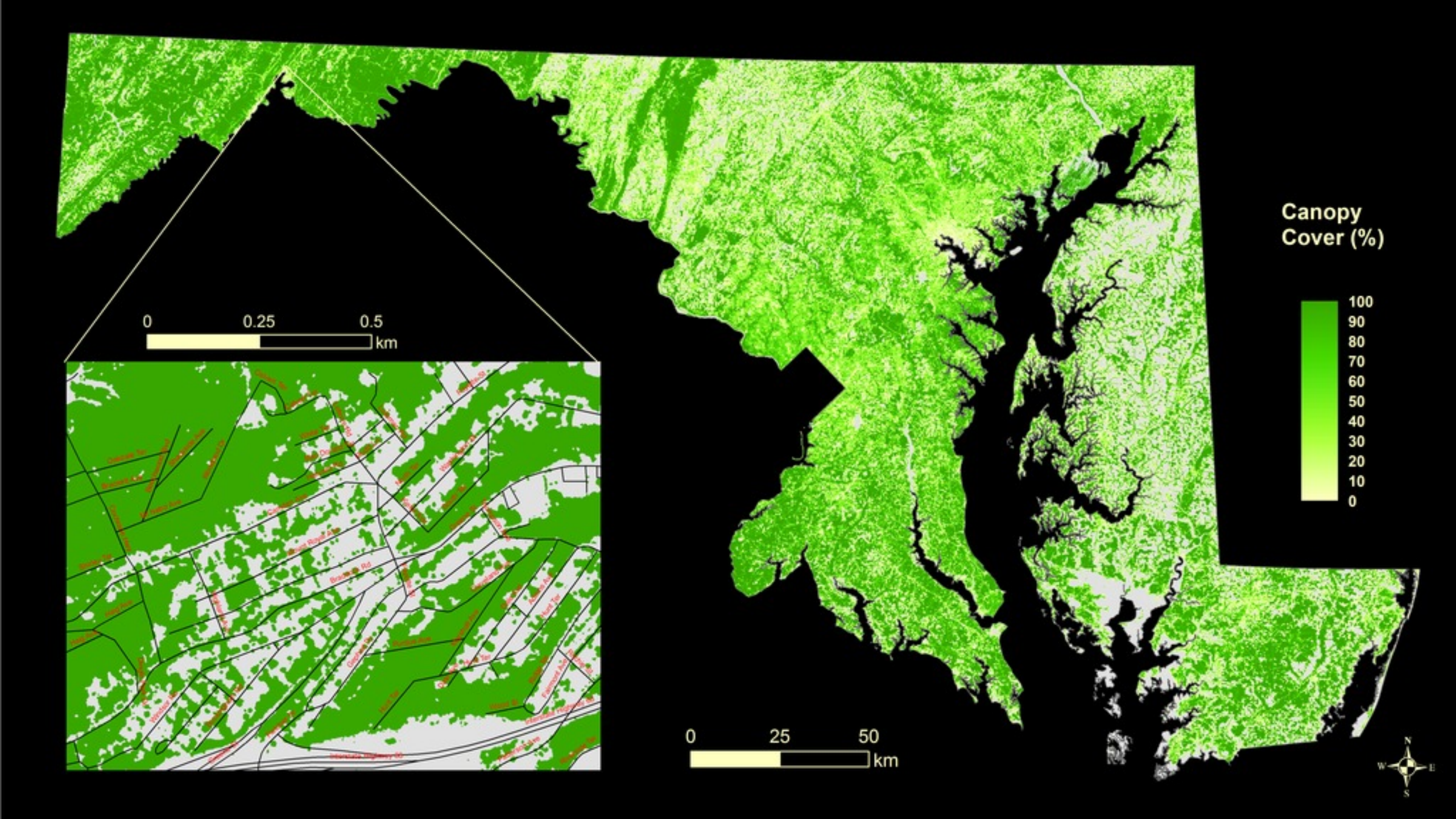


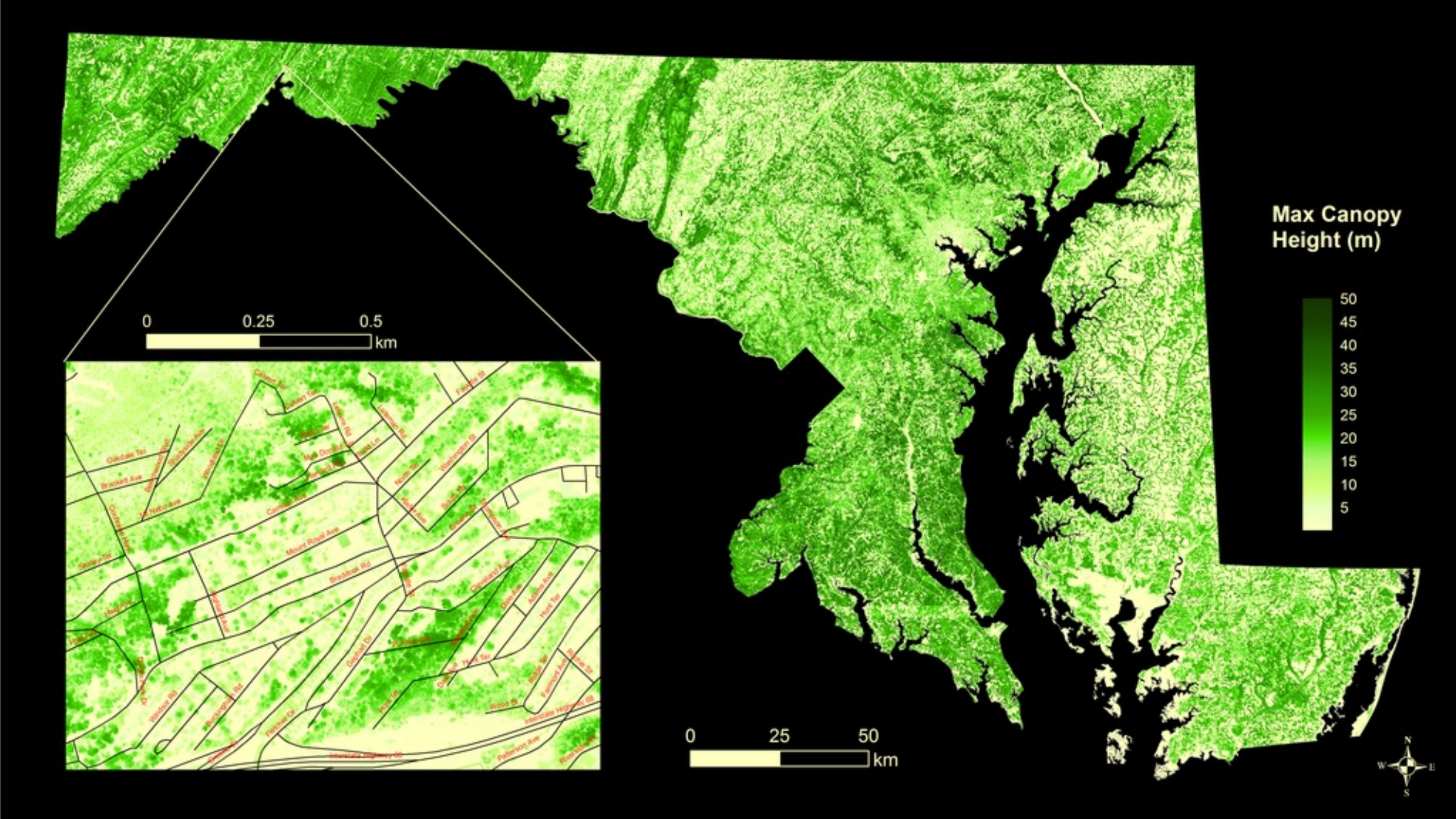
Canopy Cover Generation

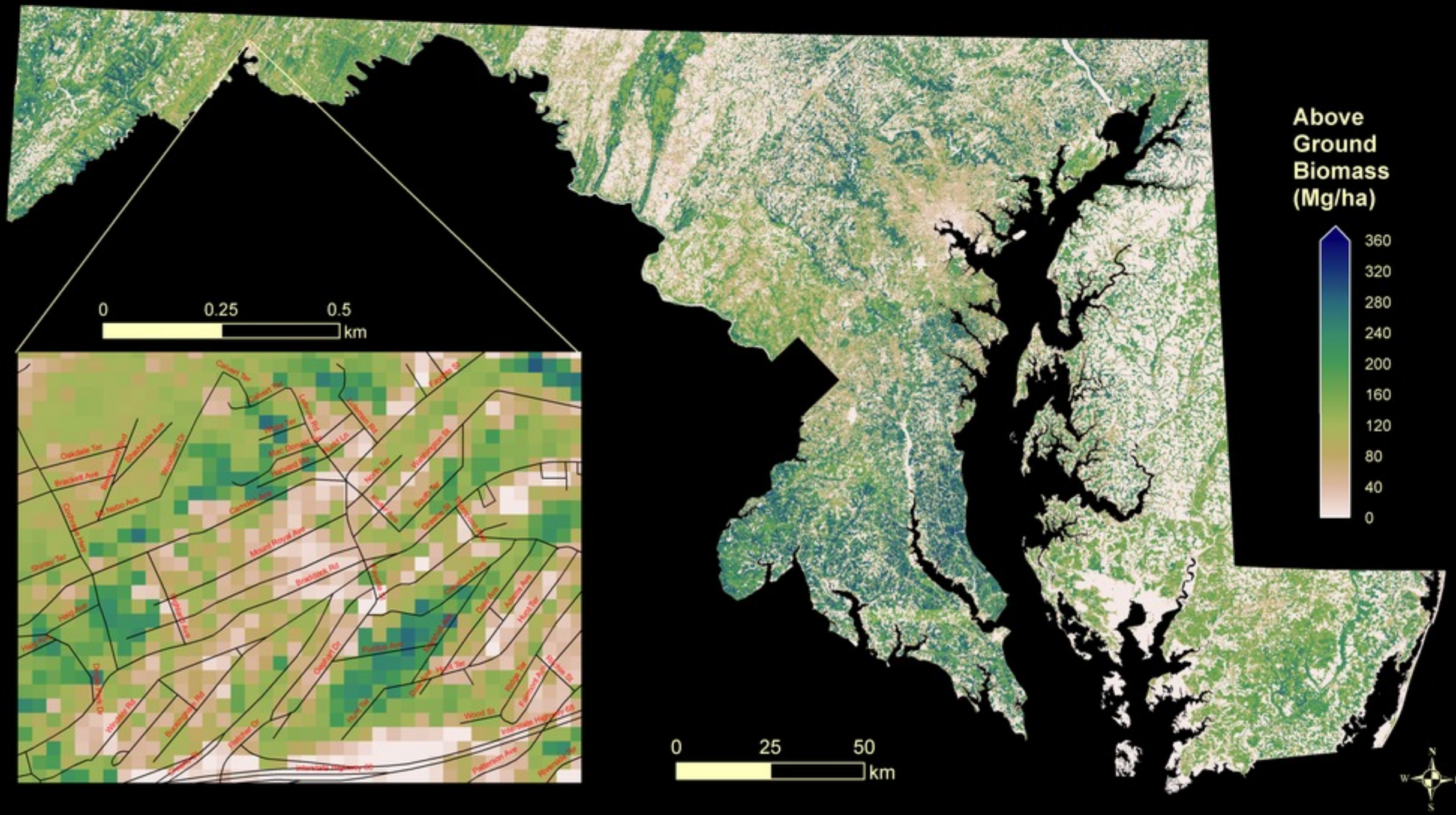


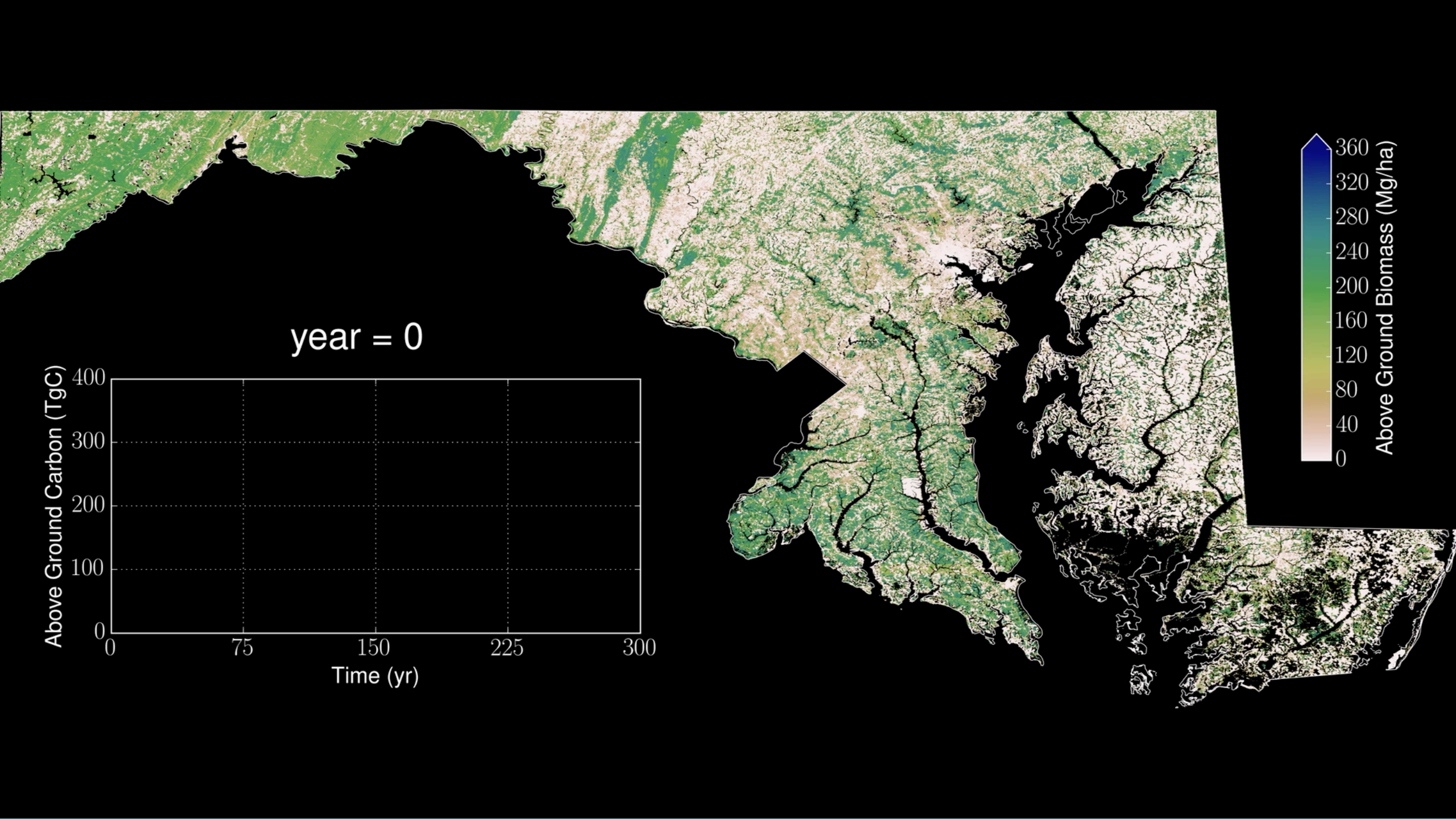





Canopy
Cover (%)
100
90
80
70
60
50
40
30
20
10
0
0
0.25
0.5
km
0
25
50
km
N
W
E
S

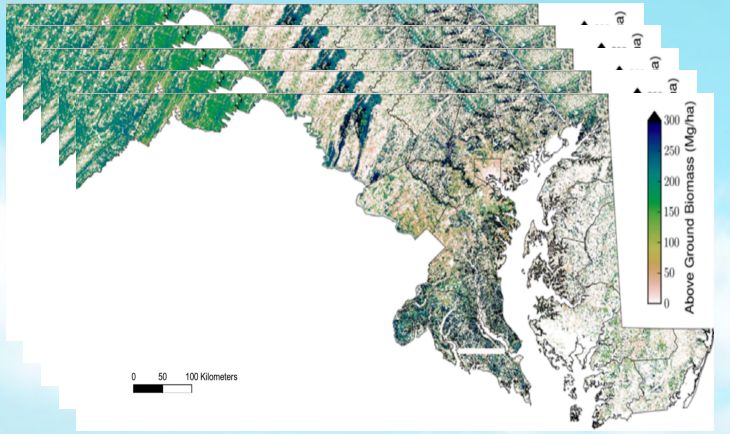

Max Canopy Height (m)
50
45
40
35
30
25
20
15
10
5
0
25
50
km
0
0.25
0.5
km
N
W
E
S


Above Ground Biomass (Mg/ha)
360
320
280
240
200
160
120
80
40
0
0
0.25
0.5
km
0
25
50
km
N
W
E
S


year = 0
Above Ground Carbon (TgC)
400
300
200
100
0
0
75
150
225
300
Time (yr)
Above Ground Biomass (Mg/ha)
360
320
280
240
200
160
120
80
40
0

USCA Monitoring Prototype - Workflow

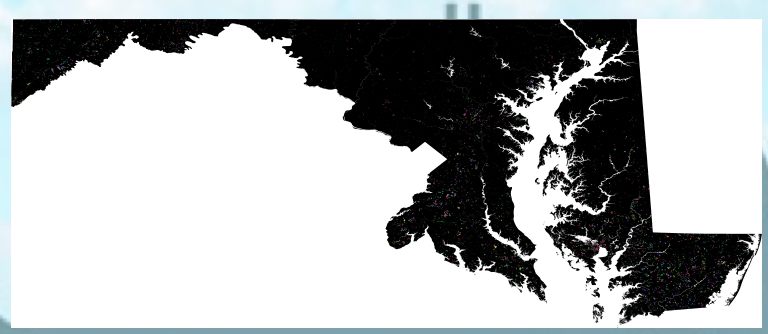
1 - Compute annual AGB gains from ED - modeled trajectories
(start year: circa 2011)



Hurtt et al. (2019)

2 – Subtract observed AGB losses in each year

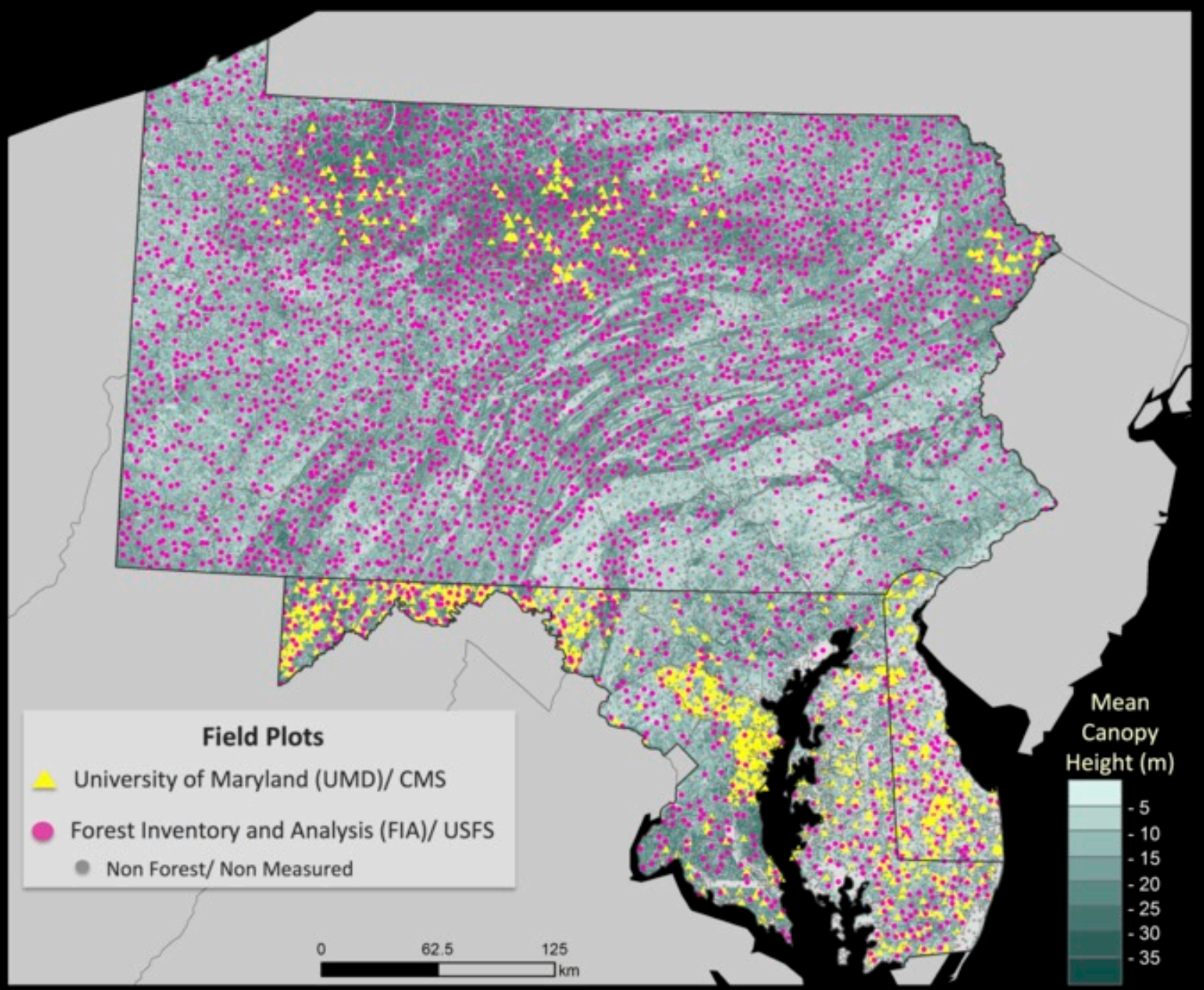
3 – Validation

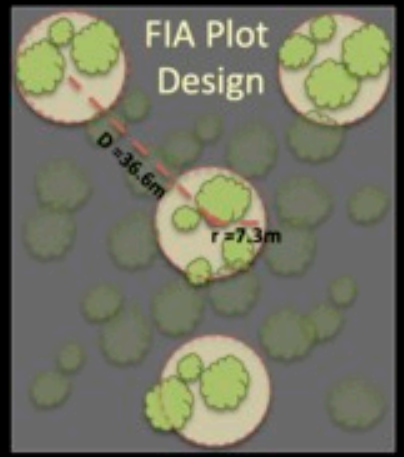


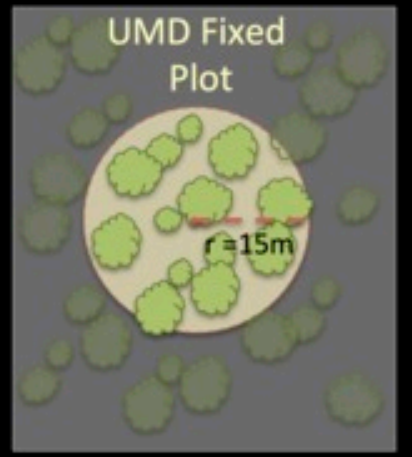
Hansen et al. (2013)

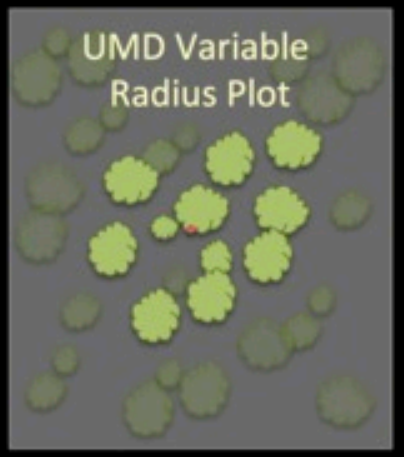
NOTE: In version 1, calculations performed only within forest area defined on start date (circa 2011)

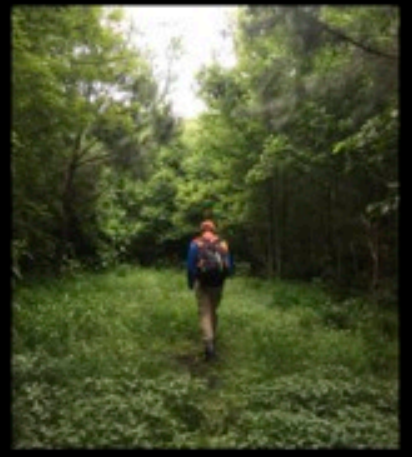
FOR DISCUSSION: How can gain/loss terms be adjusted to exactly match quantities monitored by state policy (e.g., attribution of forest growth to natural vs. human-caused)?


Field Plots
University of Maryland (UMD)/ CMS
Forest Inventory and Analysis (FIA)/ USFS
Non Forest/ Non Measured
0
62.5
125
km
Mean Canopy Height (m)
- 5
- 10
- 15
- 20
- 25
- 30
- 35


FIA Plot Design
D =36.6m
r =7.3m


UMD Fixed Plot
r =15m

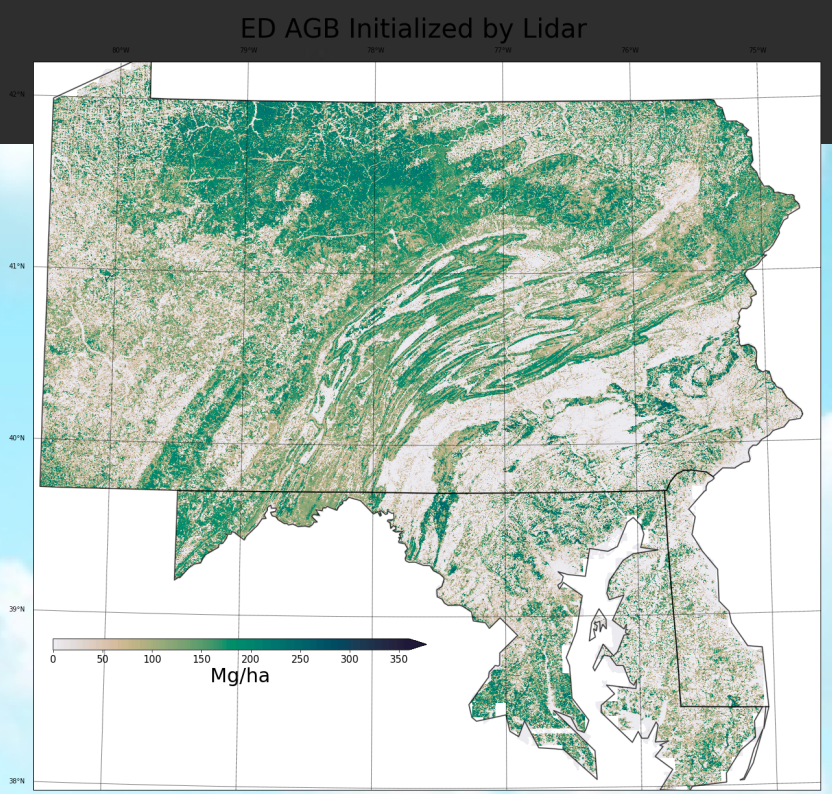

UMD Variable Radius Plot

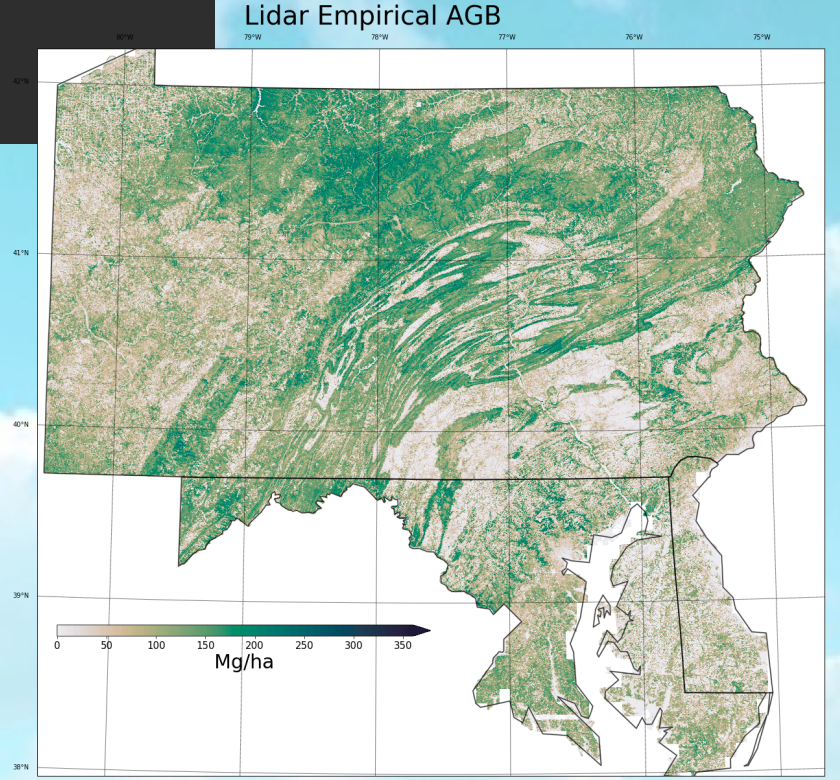


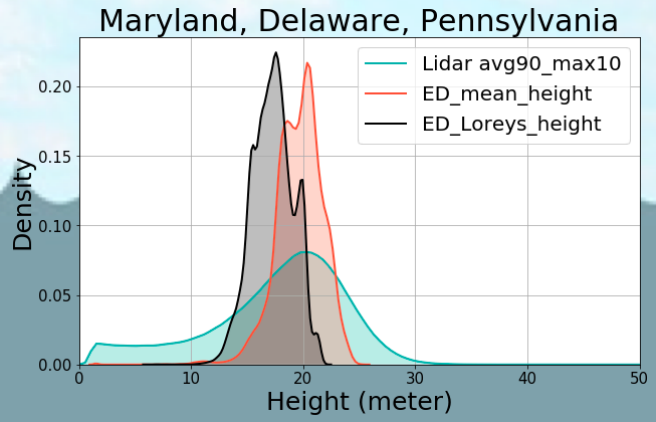
National Aeronautics and Space Administration

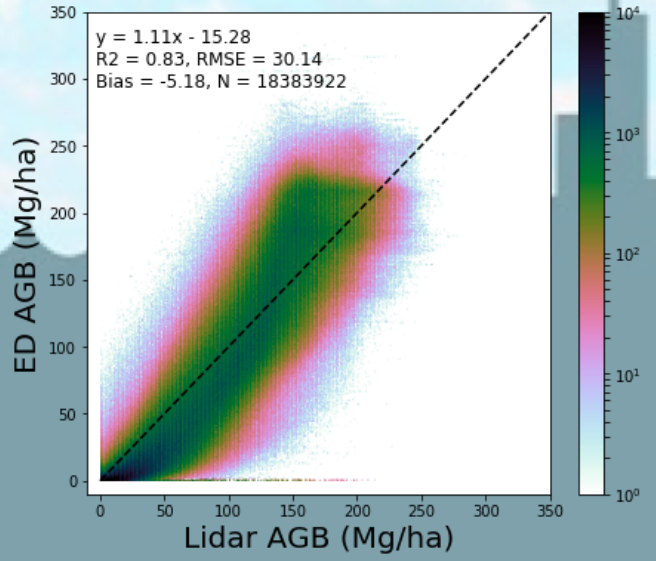
ED Test Run Over Maryland, Pennsylvania, Delaware

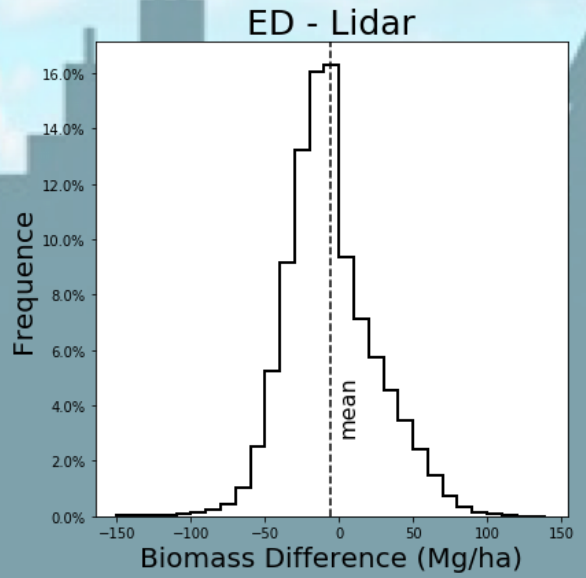
- 1km base run with DAYMET and MERRA2 as meteorology input, POLARIS as soil input
- 90m initialization with Lidar canopy height (avg90_max10) and tree cover
- 1.48 million km^2, and 18.28 million 90x90m grid
- Lidar empirical AGB is from Huang et al 2019 ERL.



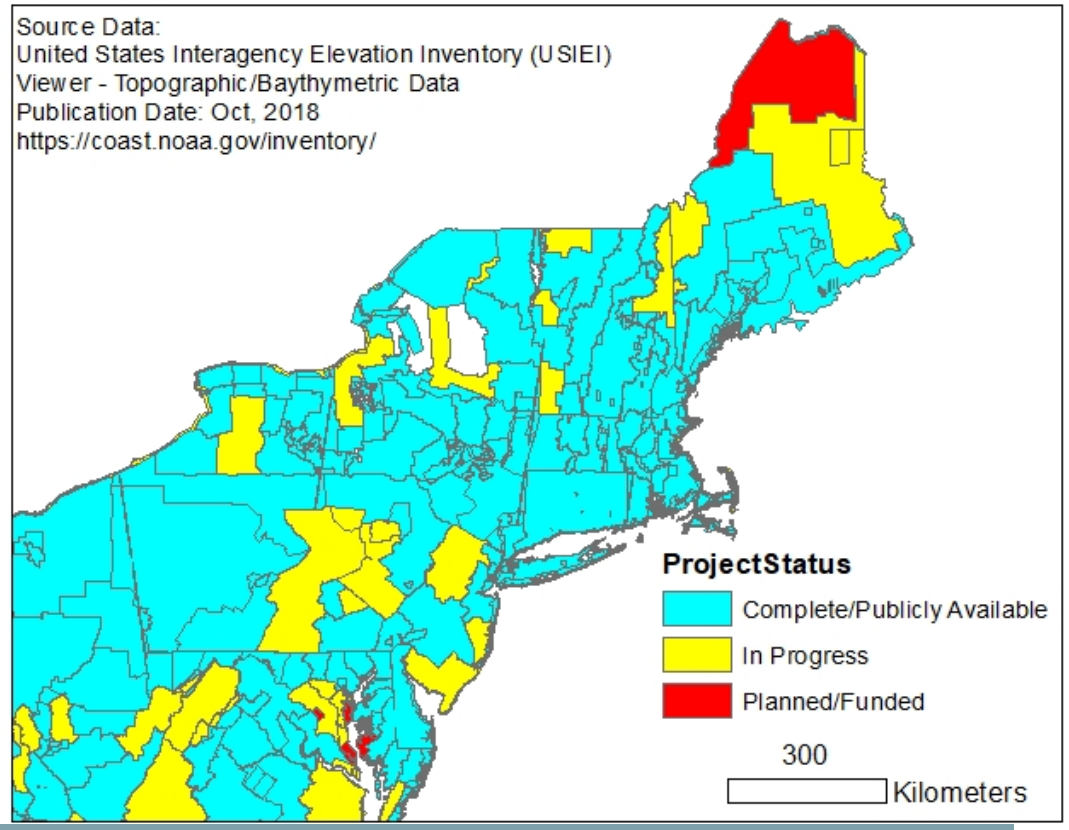


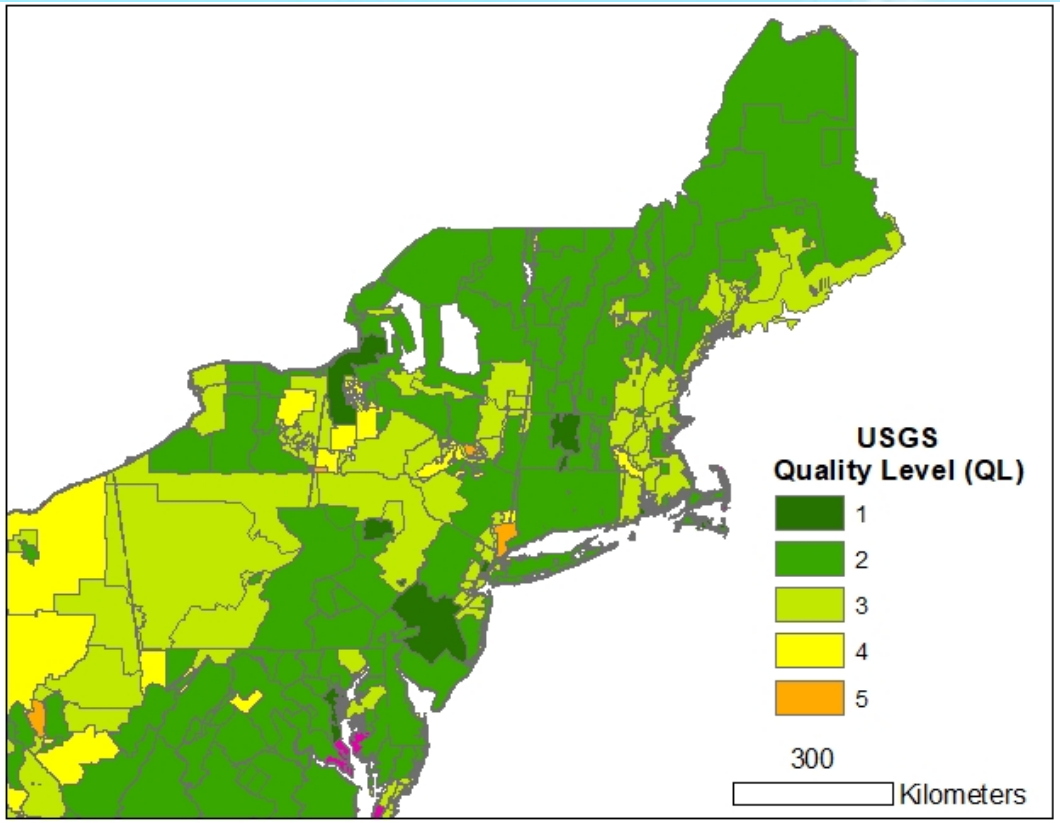


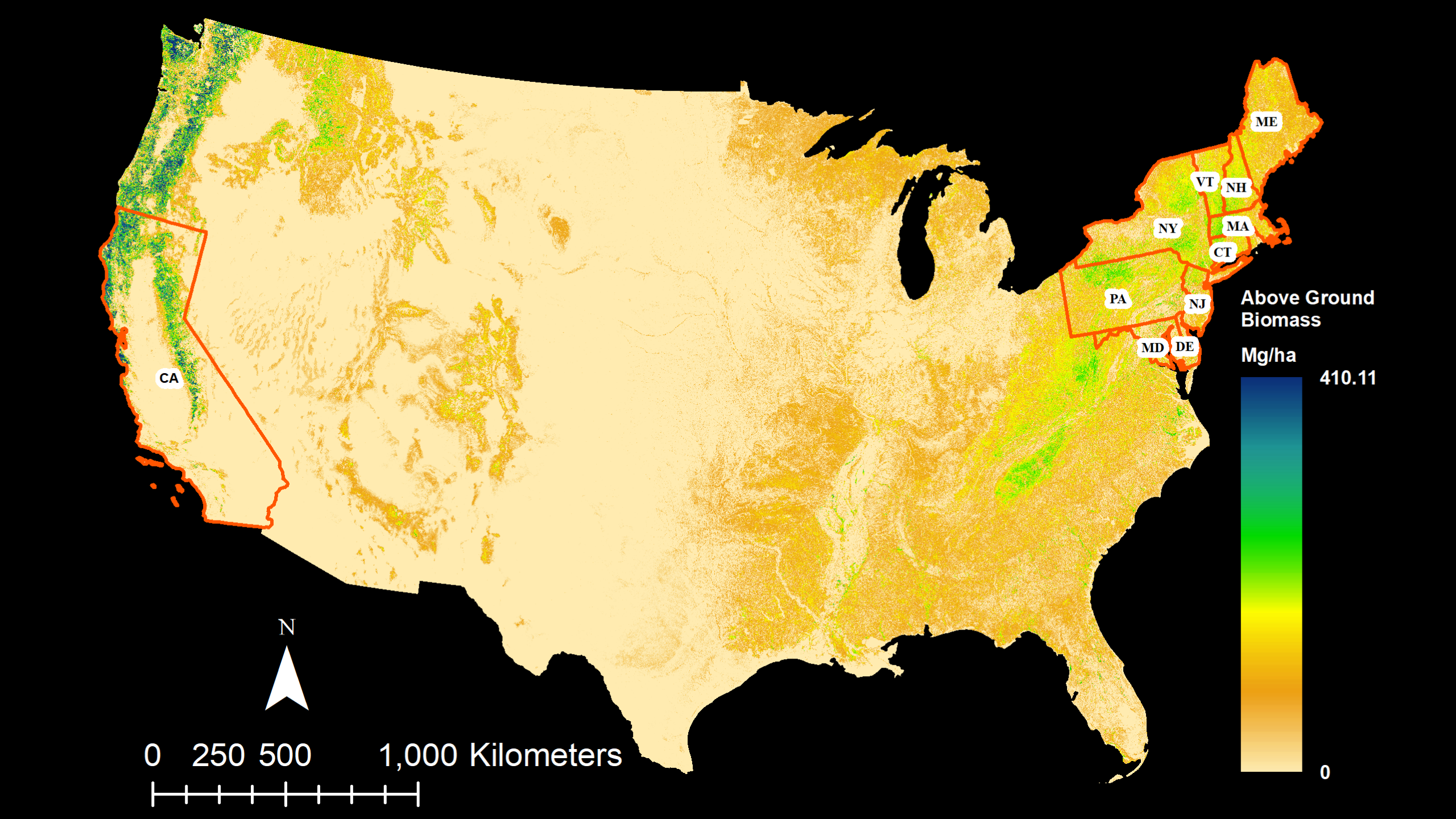




Lidar Availability






ME
VT
NH
NY
MA
CT
PA
NJ
MD
DE
CA
Above Ground Biomass
Mg/ha
410.11
0
N
0 250 500 1,000 Kilometers

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

GEDI LIDAR

Major Science Questions

What is the carbon balance of the Earth's forests?

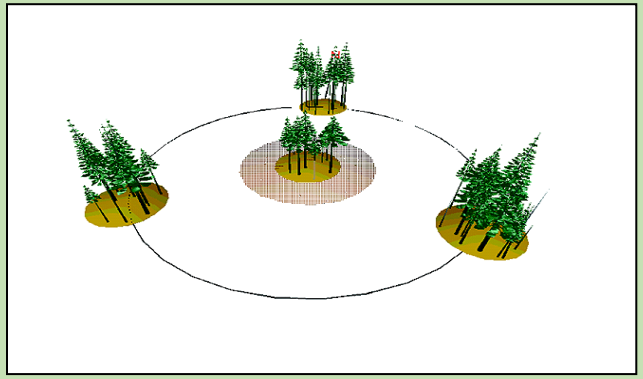
How does forest structure affect habitat quality and biodiversity?

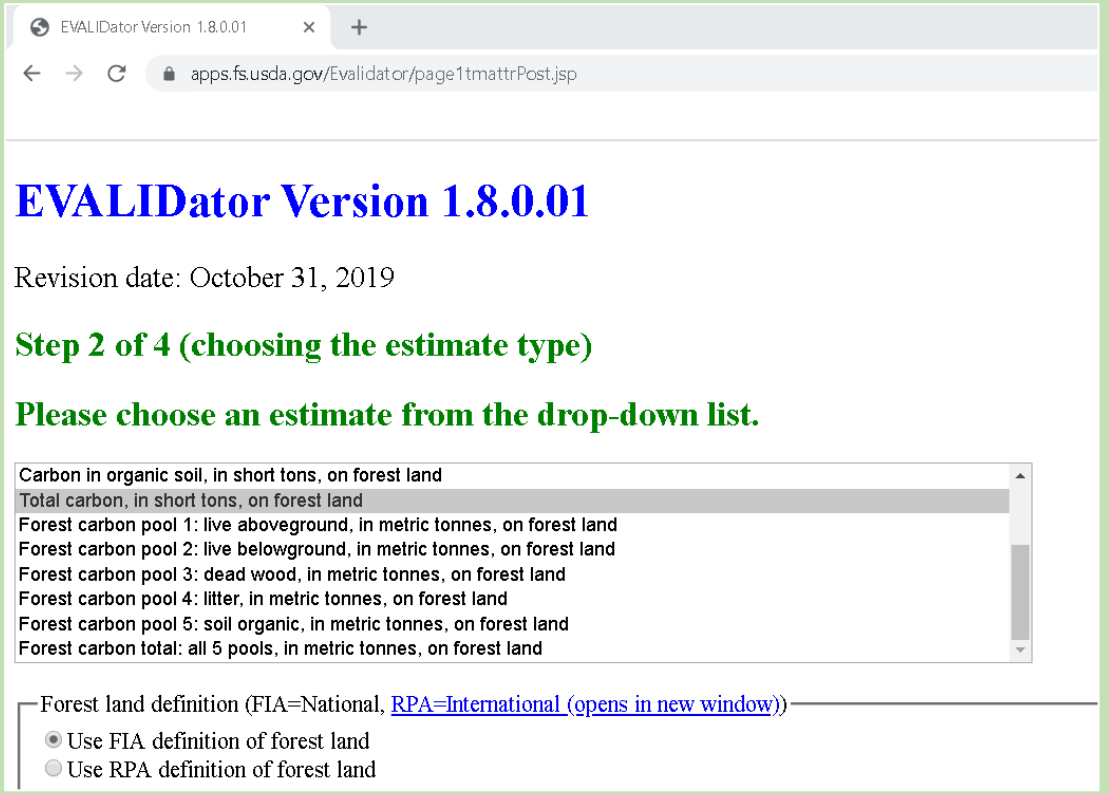
How will the land surface mitigate atmospheric CO_2 in the future?

- **Earth's first comprehensive, high-resolution data set of ecosystem structure**
- **Selected by NASA Earth Ventures Instrument Competition**
- **Led by UMD in collaboration with NASA GSFC**

How do we reconcile carbon estimates from the US Forest Service's Forest Inventory and Analysis Program with CMS estimates?

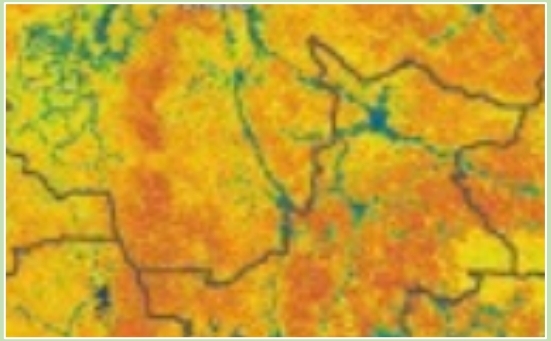
FIA estimates





CMS maps

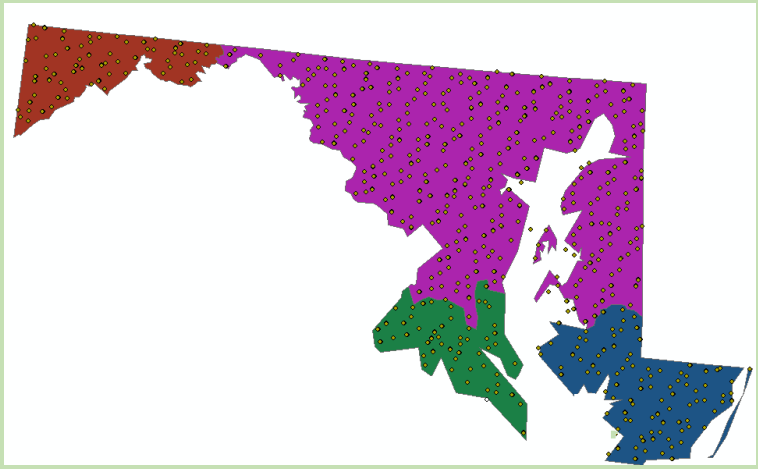
VS.



?

Inventory is designed to get at least acceptable sampling error per survey unit (for volume and forest area estimates).

FIA Survey Units



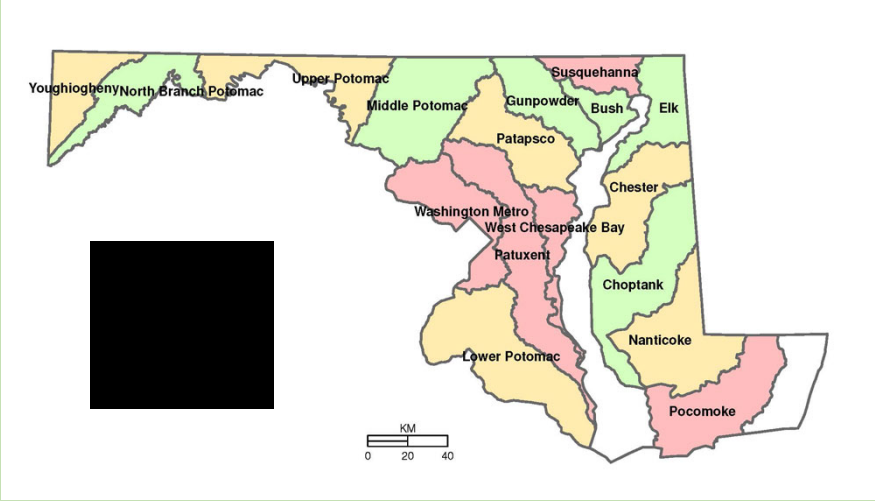
Sampling error percent (Confidence level 68%):

Note: for 95% confidence level multiply SE pct by 1.96

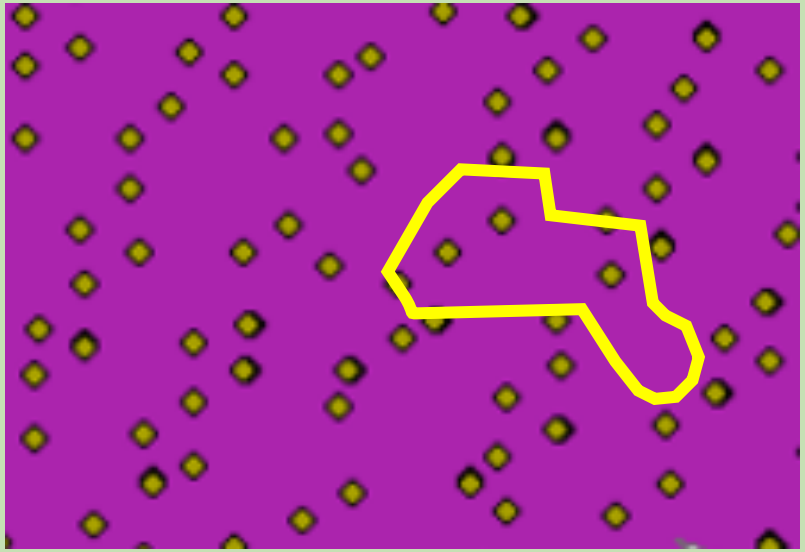
	All live stocking					
Unit code	**Total**	**Overstocked**	**Fully stocked**	**Medium stocked**	**Poorly stocked**	**Nonstocked**
Total	2.37	16.37	5.71	7.17	17.37	45.55
2402 Maryland: North Central	3.60	21.82	9.54	9.83	20.76	54.10
2403 Maryland: Southern	7.80	77.51	13.41	27.47	74.65	-
2404 Maryland: Lower Eastern Shore	4.63	26.50	10.04	20.80	50.23	66.81
2405 Maryland: Western	4.04	55.55	13.75	12.69	45.52	81.68

But for smaller geographic areas, precision is worse.

Watersheds



Even worse for tiny areas

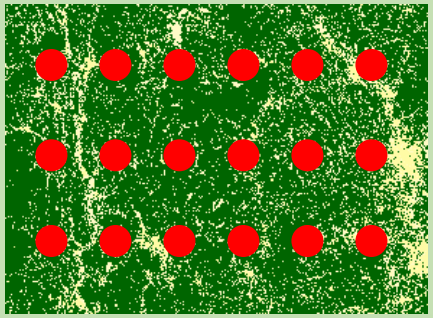


Sampling error percent (Confidence level 68%):

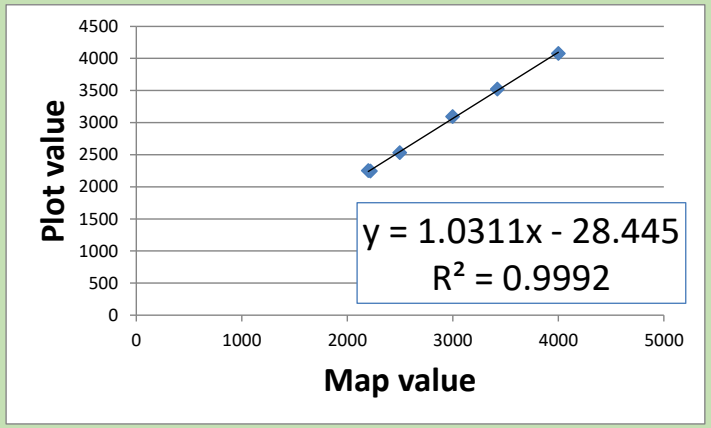
Note: for 95% confidence level multiply SE pct by 1.96

	All live stocking					
Hydrological Unit Code 8	Total	Overstocked	Fully stocked	Medium stocked	Poorly stocked	Nonstocked
Total	2.37	16.37	5.71	7.17	17.37	45.55
2040303	41.97	112.50	45.67	-	91.88	-
2050306	34.04	-	44.47	60.77	74.51	-
2060002	19.00	49.67	25.97	33.00	83.20	-
2060003	15.84	65.38	25.25	26.95	38.22	-
2060004	50.74	103.42	62.76	65.66	-	-
2060005	21.45	37.28	37.51	40.14	93.96	-
2060006	15.87	88.14	22.58	27.71	48.46	-
2070002	10.10	72.34	27.83	15.12	60.39	89.84
2070003	24.44	-	36.31	43.98	113.18	-
2070004	23.76	74.97	47.53	32.61	60.61	100.96
2070008	20.78	69.73	34.83	32.21	51.13	92.95
2070009	23.48	71.72	45.51	35.78	74.25	71.57
2070010	31.97	80.23	48.96	51.85	103.42	-
2070011	13.81	104.87	19.20	34.19	74.65	-
2080109	24.41	58.43	30.78	60.61	117.01	-
2080110	17.03	51.47	25.57	31.19	76.08	117.01
2080111	15.45	43.31	22.45	39.57	78.83	80.01
5020006	18.29	59.83	22.40	50.75	64.13	120.56

Model-assisted Regression Estimator – Get the plot values associated with the map values and apply the estimators



plot	map value	plot value
1	3423	3470
2	2221	2264
3	3000	3094
4	2200	2290
5	2498	2536
6	4001	4074



$$\widehat{y_{reg}} = \bar{y} + b(\bar{X} - \bar{x})$$

$$\widehat{VAR\{Y_{reg}\}} = \frac{s^2_{X.Y}}{n}\left(1 - \frac{n}{N}\right)$$

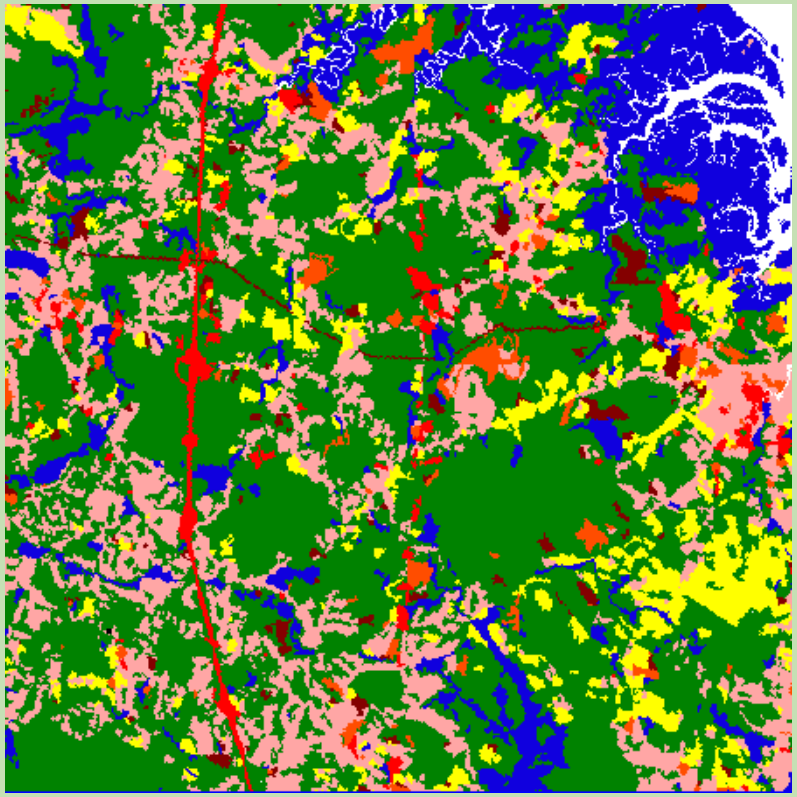
Lower variance than without the maps!

where

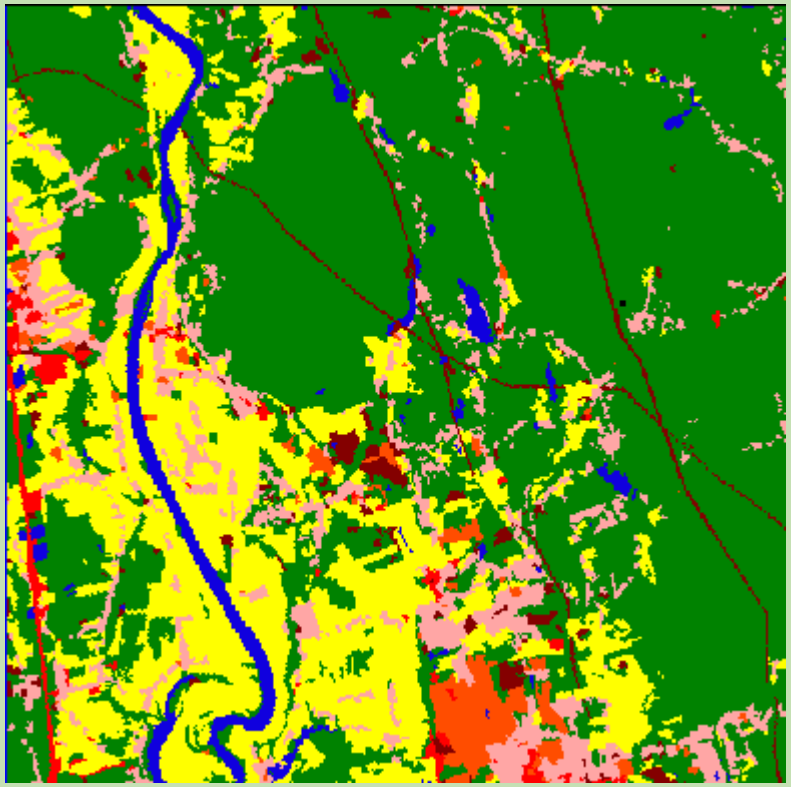
$$s^2_{X.Y} = \frac{\sum_{i=1}^{n}(yi-\bar{y})^2 - b^2 \sum_{i=1}^{n}(xi-\bar{x})^2}{n-2}$$

The point is, CMS maps can help fill in holes where there are no plots, improve estimates for smaller geographic areas, and provide high quality information for other resource management tasks…

~60 % Forest



~60 % Forest



Forest fragmentation, habitat assessments, scenario planning, multicriterion modelling….

State Name	Policy Framework	Goal	Science (Land)	Science needs (Land)
Maryland	Greenhouse Gas Emissions Reduction Act (enacted 2009, updated 2016), Forest Conservation Act (enacted 1991, updated 2013)	40% below 2006 levels by 2030, 80-95% below 2006 levels by 2050	NASA-CMS, USFS, NLCD	Annual flux monitoring
Pennsylvania	Climate Change Action Plan (Update 2018), State Forest Resource Management Plan (Update 2016)	26% below 2005 levels by 2025, 80% below 2005 levels by 2050	USFS, NLCD	
Delaware	Climate Framework for Delaware (2014)	Recommended target of 30% below 2008 levels by 2030	USFS, NLCD	
New York	New York State Energy Plan (2015), Executive Order 166	40% below 1990 levels by 2030, 80% below 1990 levels by 2050	U.S. National GHG Inventory	Integrate forest sector, harvest monitoring, model verification
Vermont	Vermont Climate Action Commission Final Report (2018), Comprehensive Energy Plan (2016)	40% below 1990 levels by 2030, 80 to 90% below 1990 levels by 2050	FIA, National Forest Carbon Inventory	Annual changes in carbon flux values, high resolution carbon sequestration estimates
Massachusetts	The Global Warming Solutions Act 2008 (GWSA), Clean Energy and Climate Plan for 2020	25% below 1990 levels by 2020, 80% below 1990 levels by 2050	Massachusetts Annual Greenhouse Gas Emissions Inventory 1990-2016	Existing natural and working lands as net carbon sinks, LiDAR capabilities
Connecticut	CT Global Warming Solutions Act (PA 08-98) An Act Concerning Climate Change Planning and Resiliency (PA 18-82)	10% below 1990 levels by 2020, 45% below 2001 levels by 2030, 80% below 2001 levels by 2050	EPA's State Inventory Tool (SIT)	More reliable LULC and forestry data
Rhode Island	Rhode Island Greenhouse Gas Emissions Reduction Plan (2016)	10% below 1990 levels by 2020, 45% below 1990 levels by 2035, 80% below 1990 levels by 2050	iTree Canopy Tool	Fully understand mitigation potential of urban forests
New Jersey	Global Warming Response Act (2007, revised 2019), Clean Energy Act (2018)	Limit to or below 1990 levels by 2020, 80% below 2006 levels by 2050	NJDEP land use land cover data	Updated land use data, soil carbon data, and improved monitoring and measurement methods
New Hampshire	The New Hampshire Climate Action Plan	20% below 1990 levels by 2025, 80% below 1990 levels by 2050		
Maine	Maine Legislature, 38 MRSA §576	10% below 1990 levels by 2020, 75% to 80% below 2003 levels may be required		

NH 2009 Climate Action Plan & Forestry Model

Chris Skoglund
Climate & Energy Program Manager
Christopher.Skoglund@des.nh.gov
603-271-7624

2009 NH Climate Action Plan Process

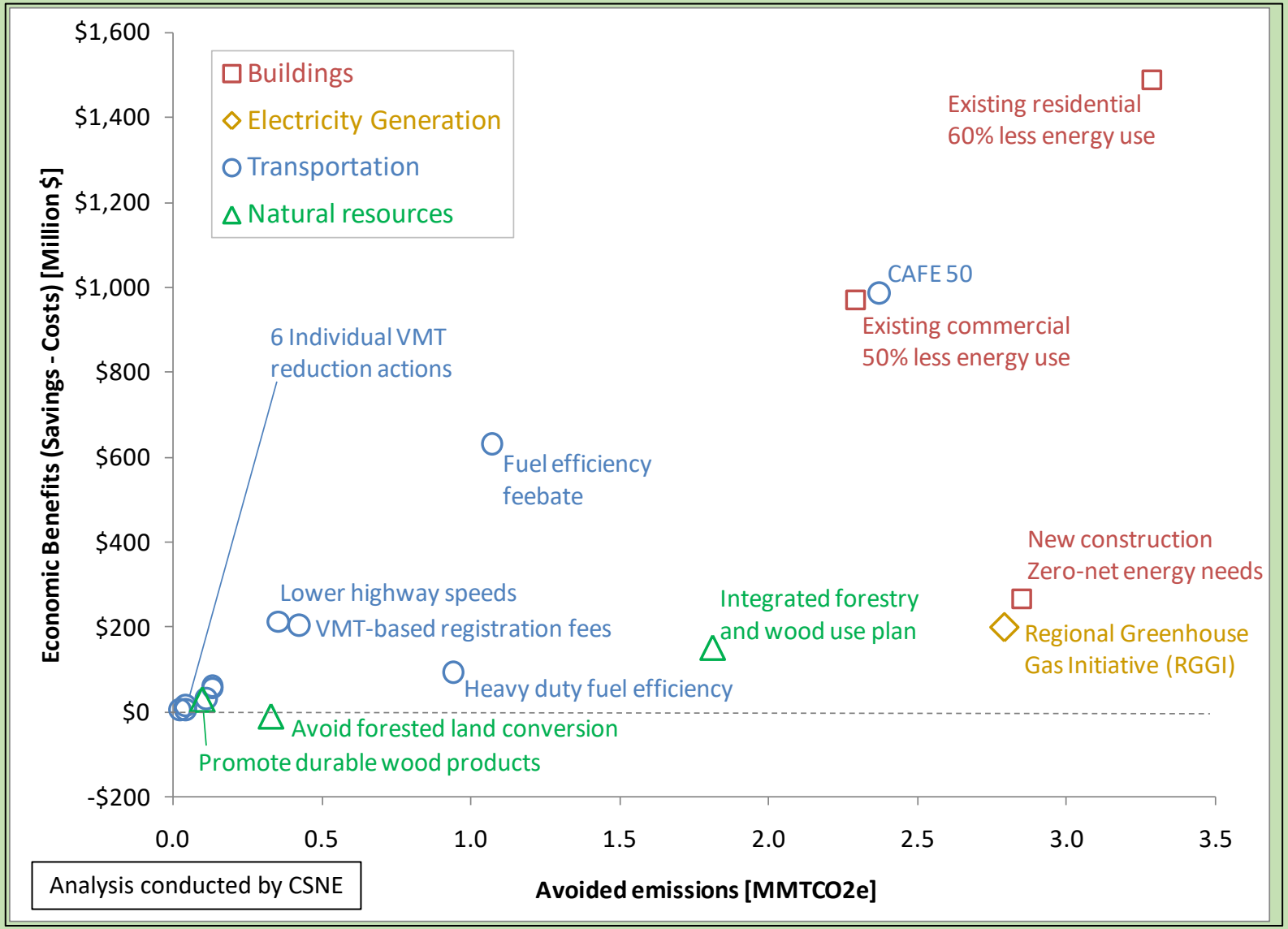
- Climate Policy Task Force
  - Established through Executive Order 2007-3 December 6, 2007
  - Supported by six working groups over 12 month planning process
  - Establish quantified greenhouse gas emission reduction goals
    - 20% below 1990 levels by 2025
    - 80% below 1990 levels by 2050
  - Recommend specific actions to achieve its greenhouse gas emission reduction goals

Essential Strategies to Achieve Goals

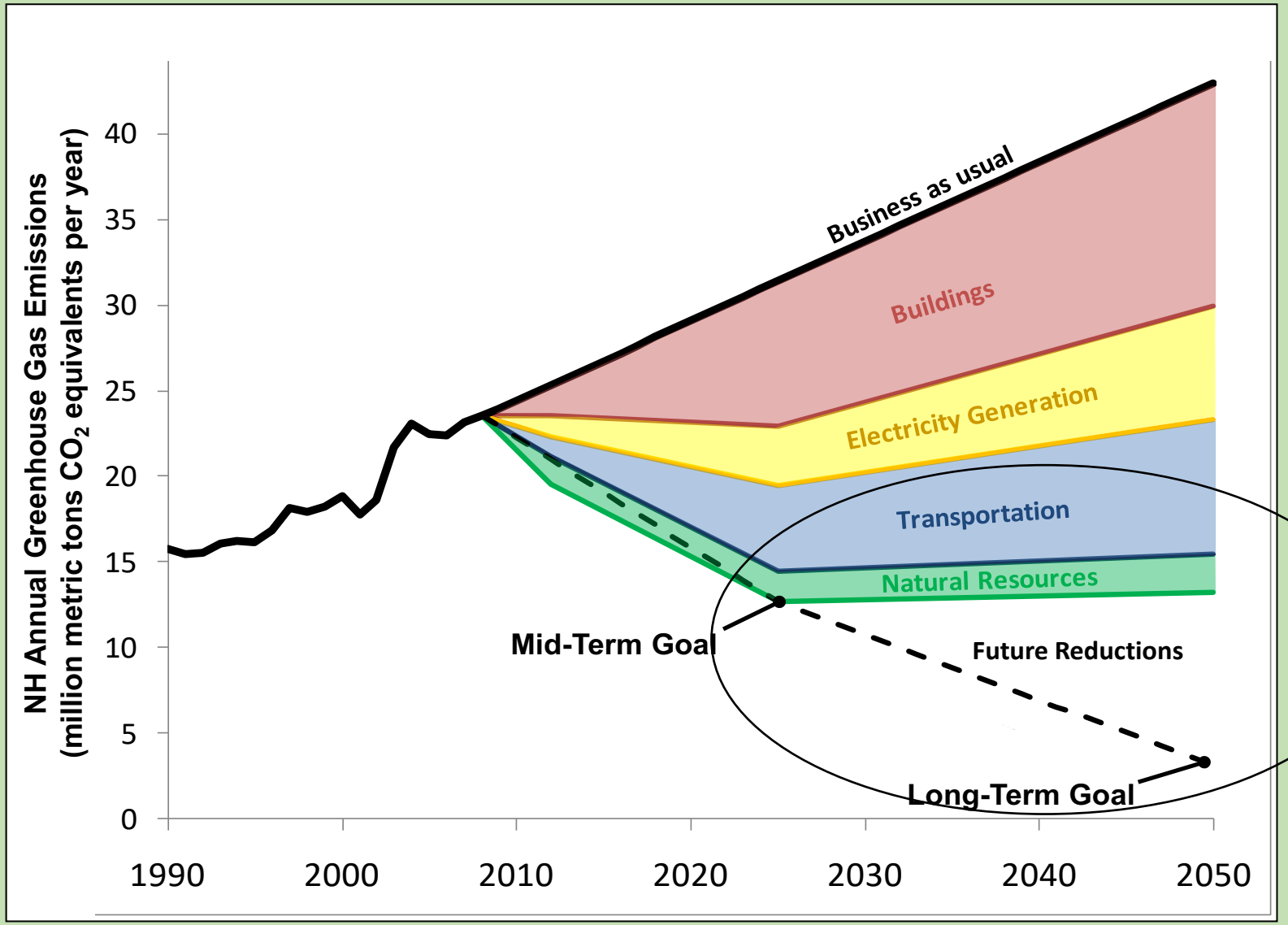
1. Maximize energy efficiency in buildings and transportation;
2. Increase renewable and low-CO2-emitting heat and electric power sources;
3. **Protect our natural resources to maintain the amount of carbon sequestered;**
4. Educate in ways that focuses on raising the awareness, knowledge and skills of NH residents related to climate change and its solutions; and
5. Adapt to the impacts of existing and potential climate change.

Emission Reduction Modeling

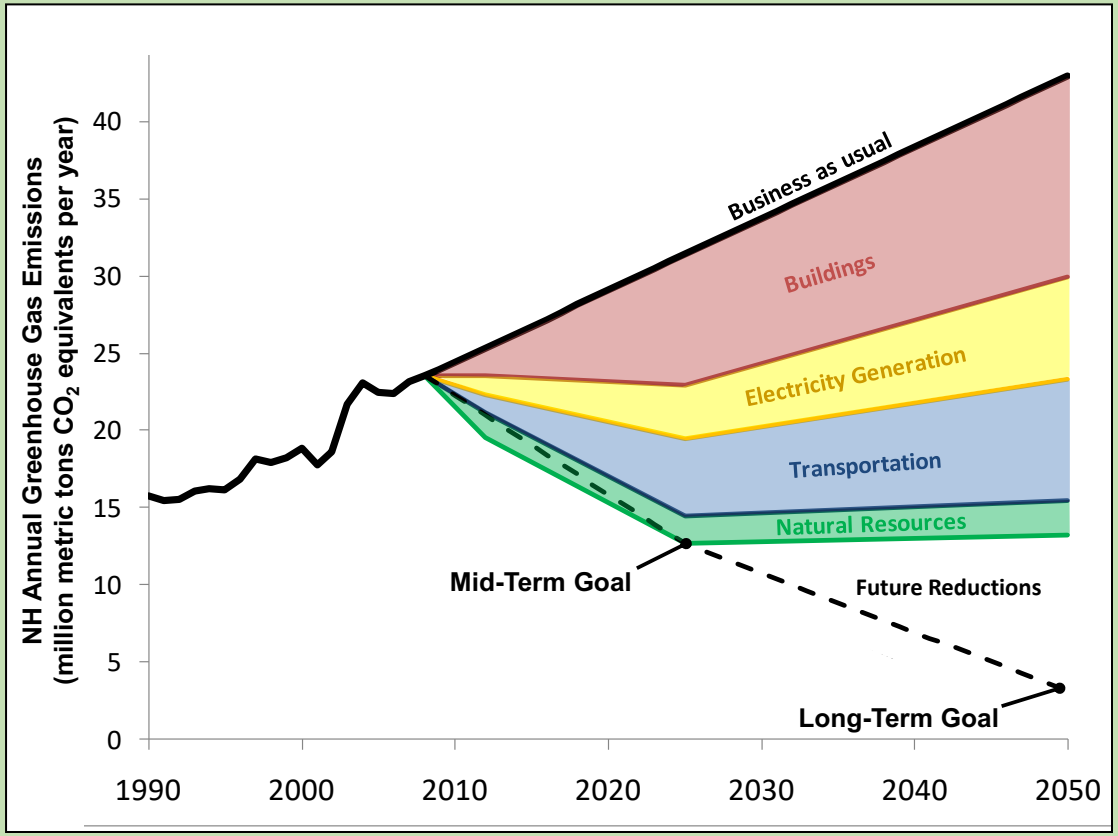
Economic Benefits and Avoided Emission Reductions

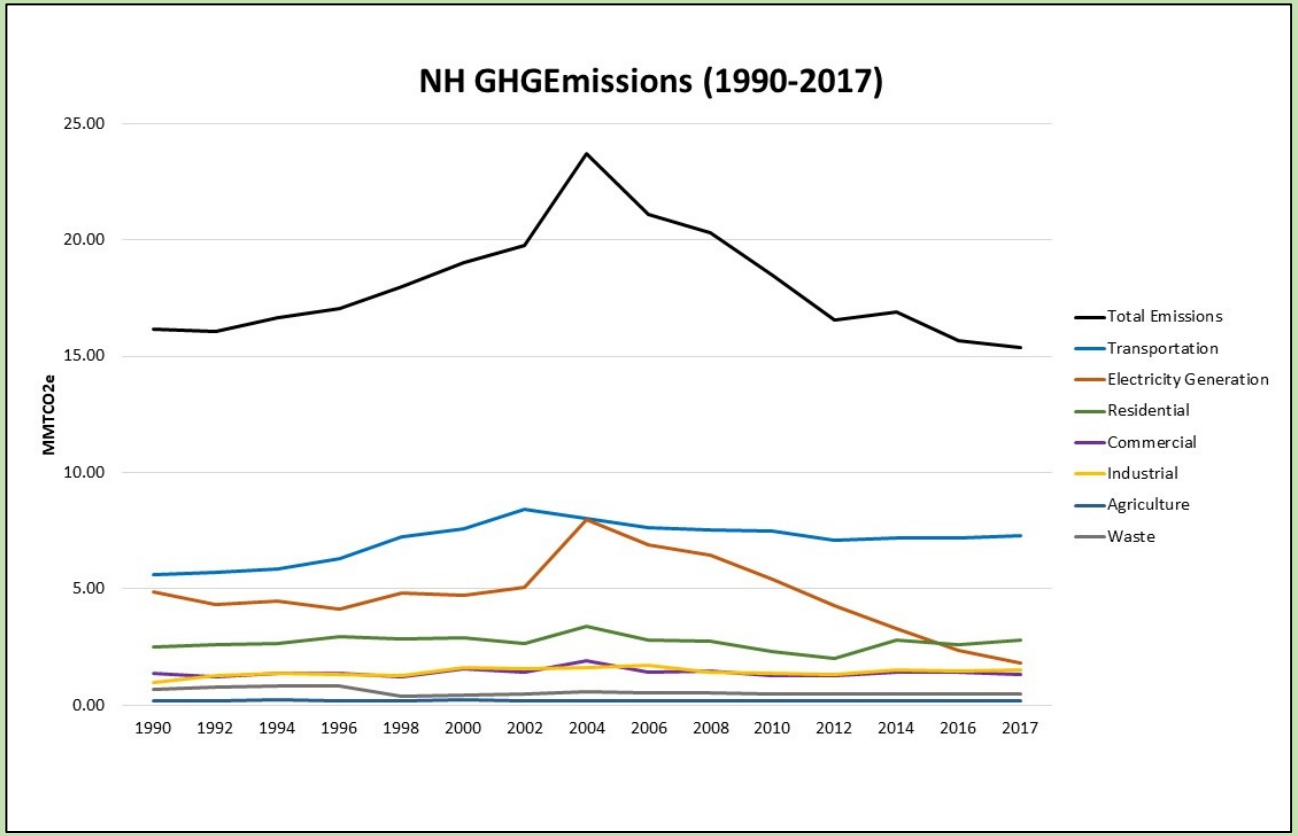


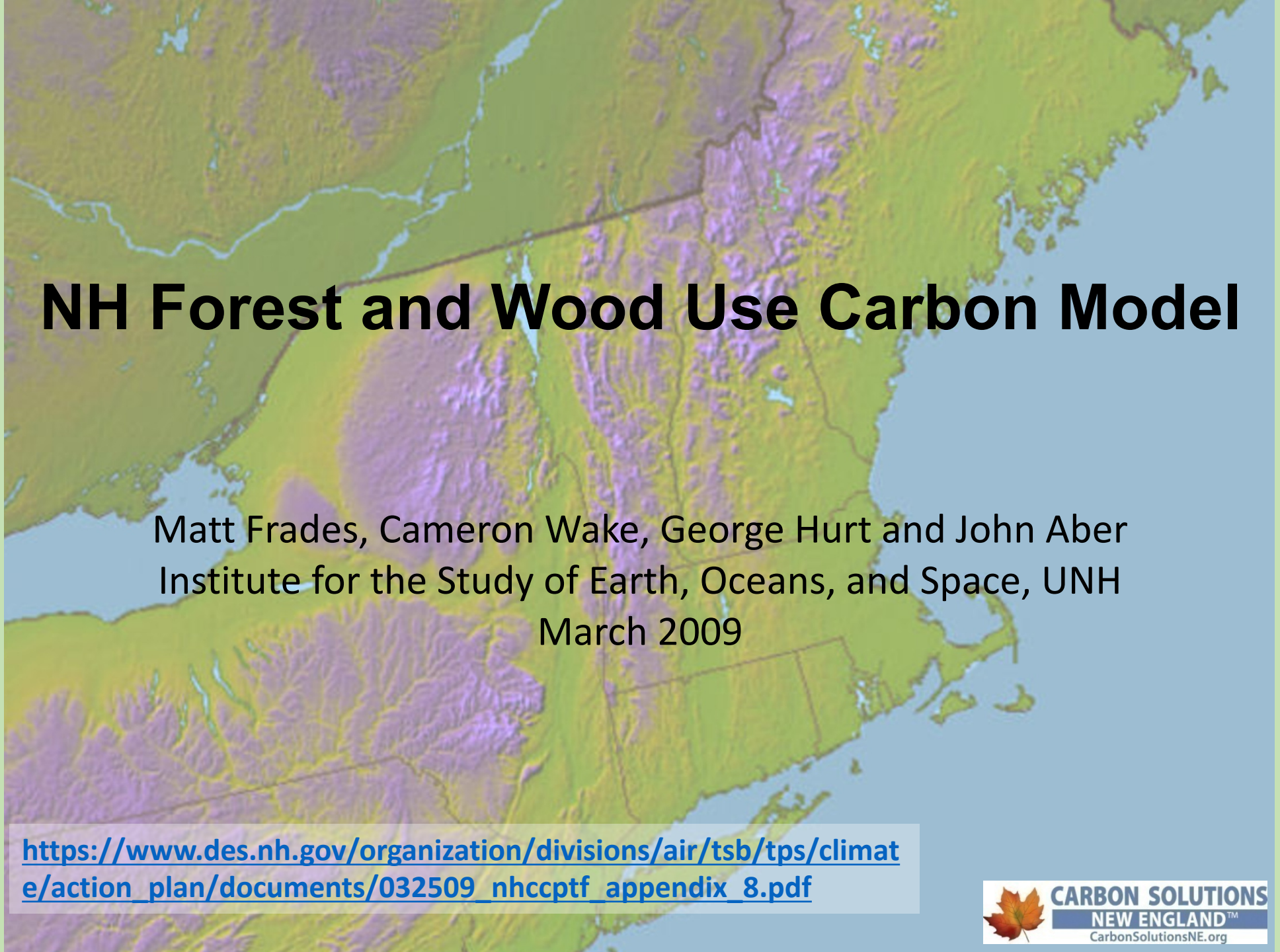
Emission Reduction Modeling



Emission Reductions – Proposed vs. Actual







NH Forest and Wood Use Carbon Model

Matt Frades, Cameron Wake, George Hurt and John Aber
Institute for the Study of Earth, Oceans, and Space, UNH
March 2009

https://www.des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/documents/032509_nhccptf_appendix_8.pdf

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Elements and Considerations of Forest Model

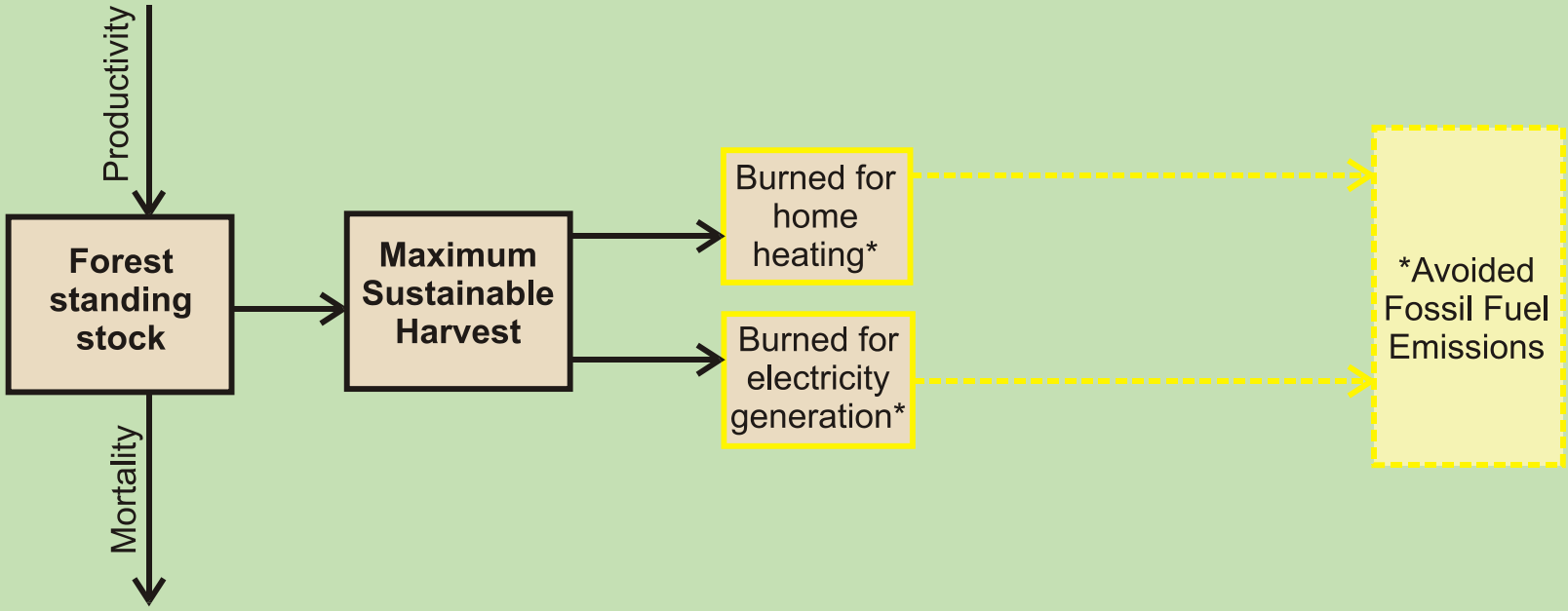
- Interest in the following actions:
    - Reducing forested land conversion rates
    - Wood for energy
        - Home heating
        - Electricity
    - Durable product promotion
    - Changes in harvest amount
    - Maintaining an economically and ecologically sustainable working forest

→ These actions interact!

- What is the estimated net impact of NH forest management on atmospheric greenhouse gas levels?

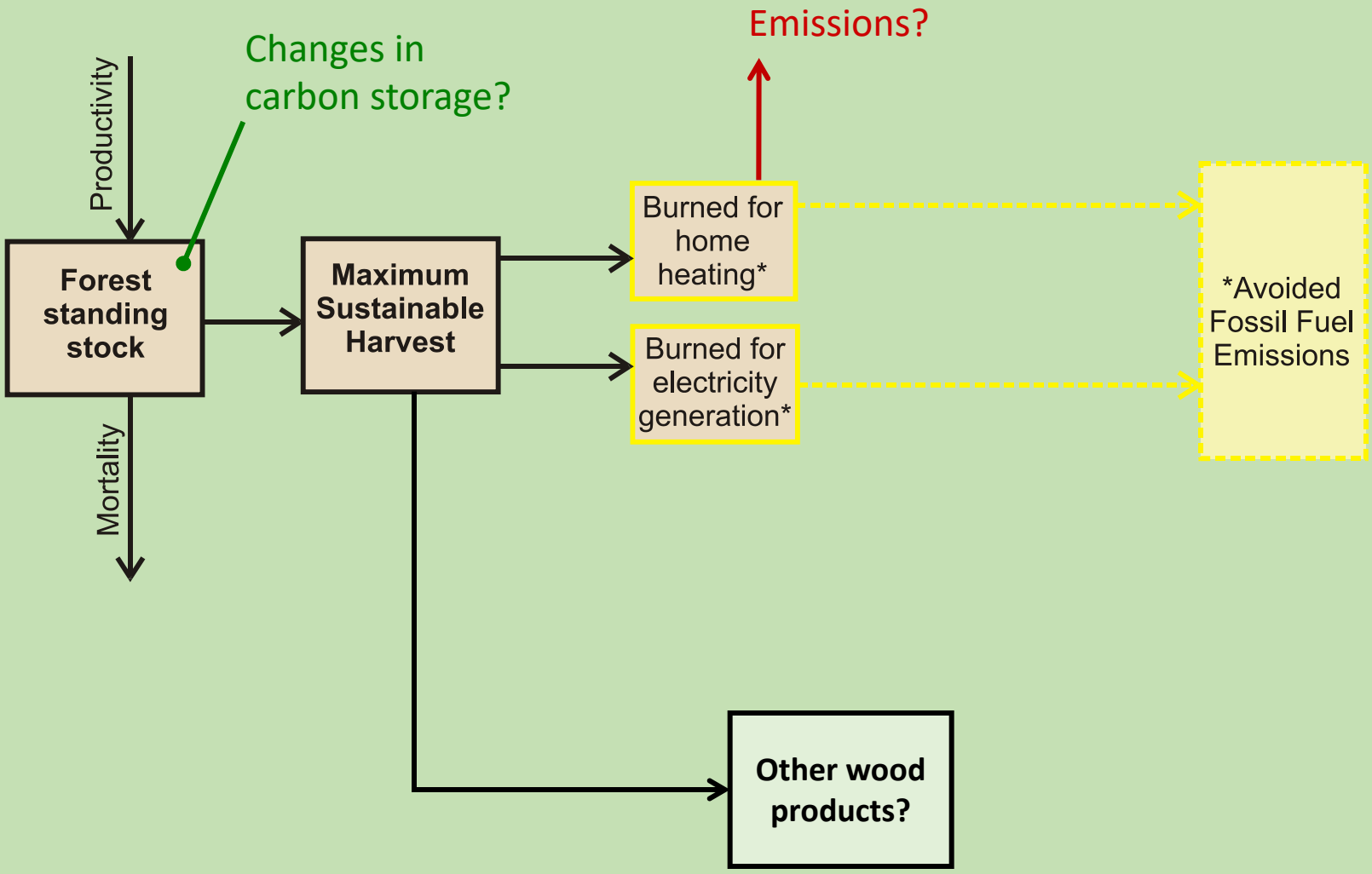
Why a revised forest model?

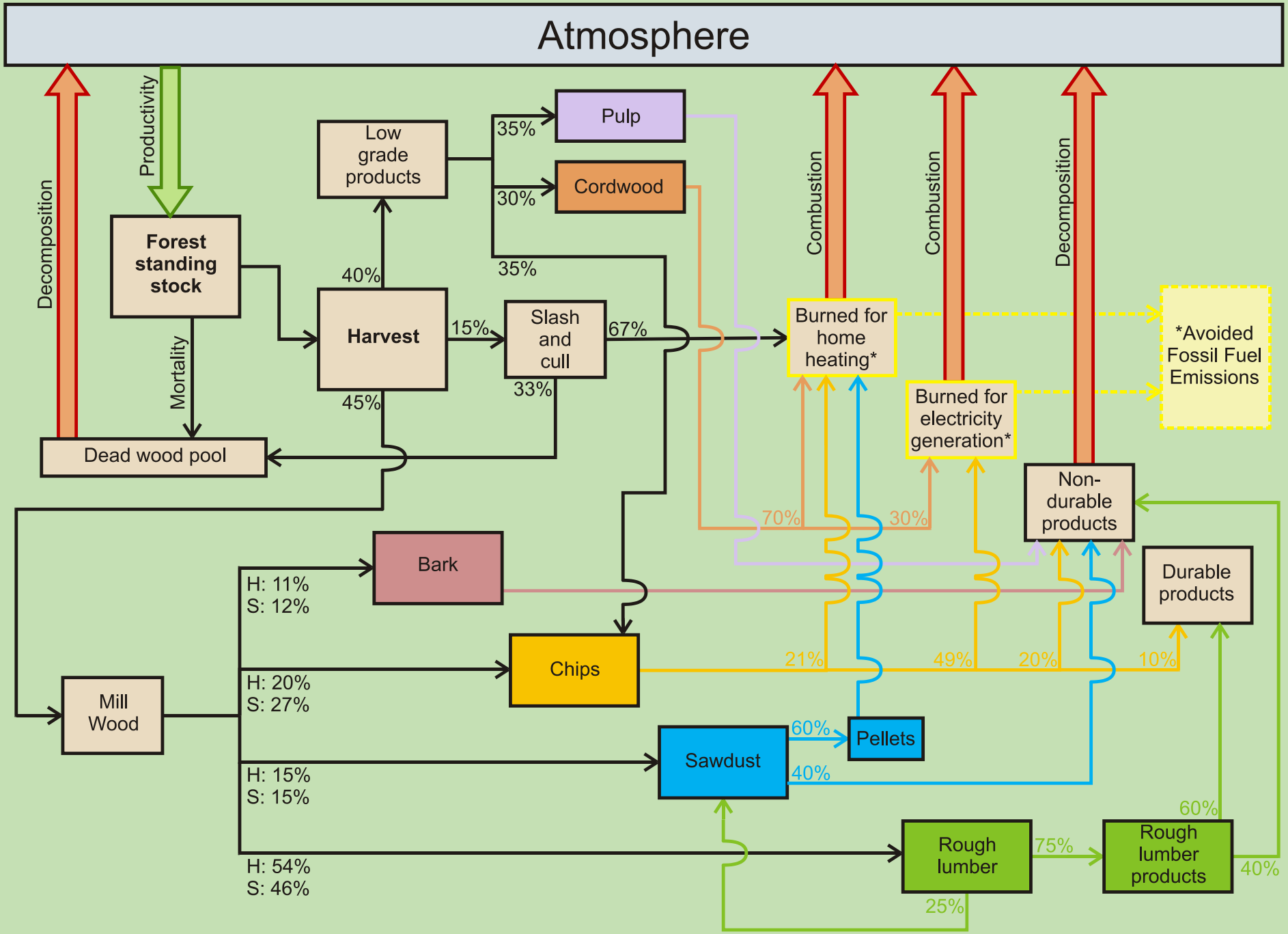
Wood for energy model



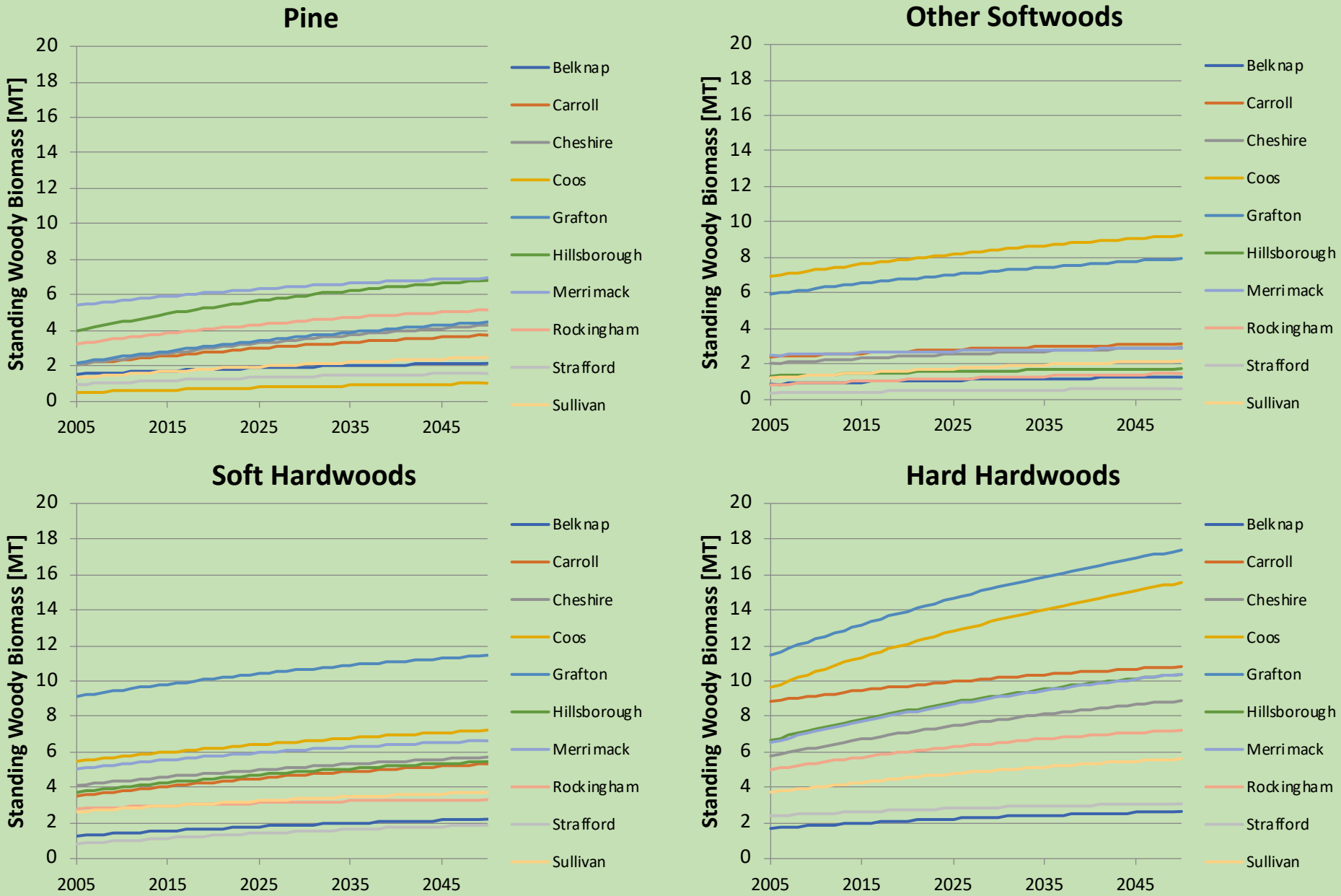
Why a revised forest model?

Wood for energy model

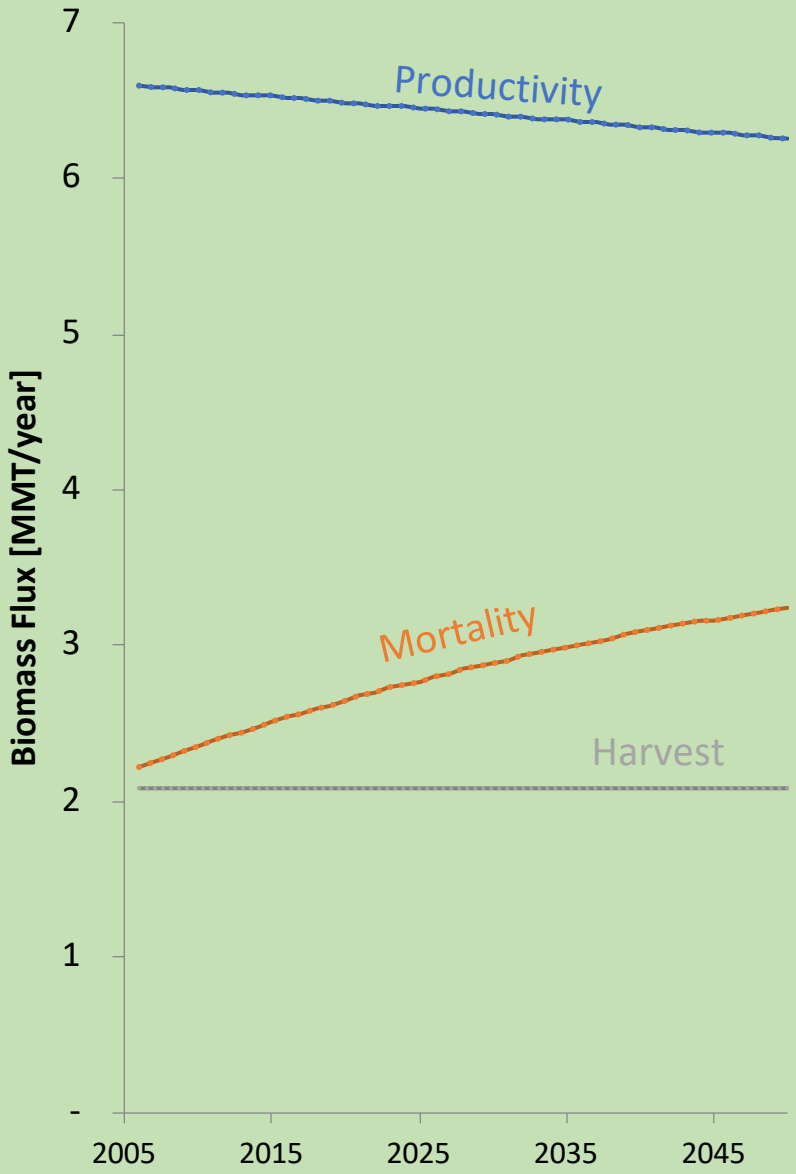


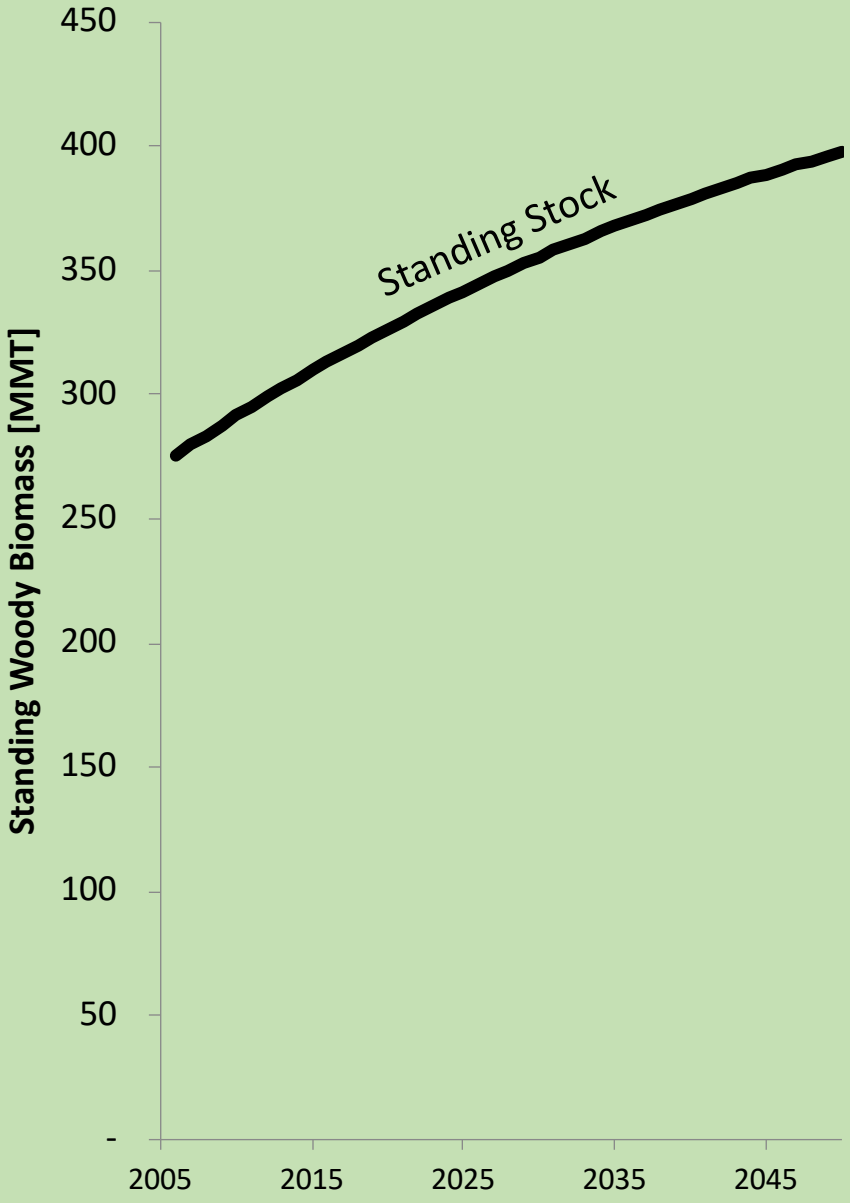

Atmosphere
Decomposition
Productivity
Forest standing stock
Mortality
Dead wood pool
Low grade products
40%
Harvest
45%
15%
Slash and cull
33%
67%
35%
Pulp
30%
Cordwood
35%
Combustion
Combustion
Decomposition
Burned for home heating*
Burned for electricity generation*
*Avoided Fossil Fuel Emissions
Non-durable products
Durable products
70%
30%
Bark
H: 11%
S: 12%
Chips
21%
49%
20%
10%
Mill Wood
H: 20%
S: 27%
H: 15%
S: 15%
H: 54%
S: 46%
Sawdust
60%
Pellets
40%
Rough lumber
75%
Rough lumber products
60%
40%
25%

Model Output (BAU): Standing Woody Biomass
(10 counties, 4 Forest Classes)

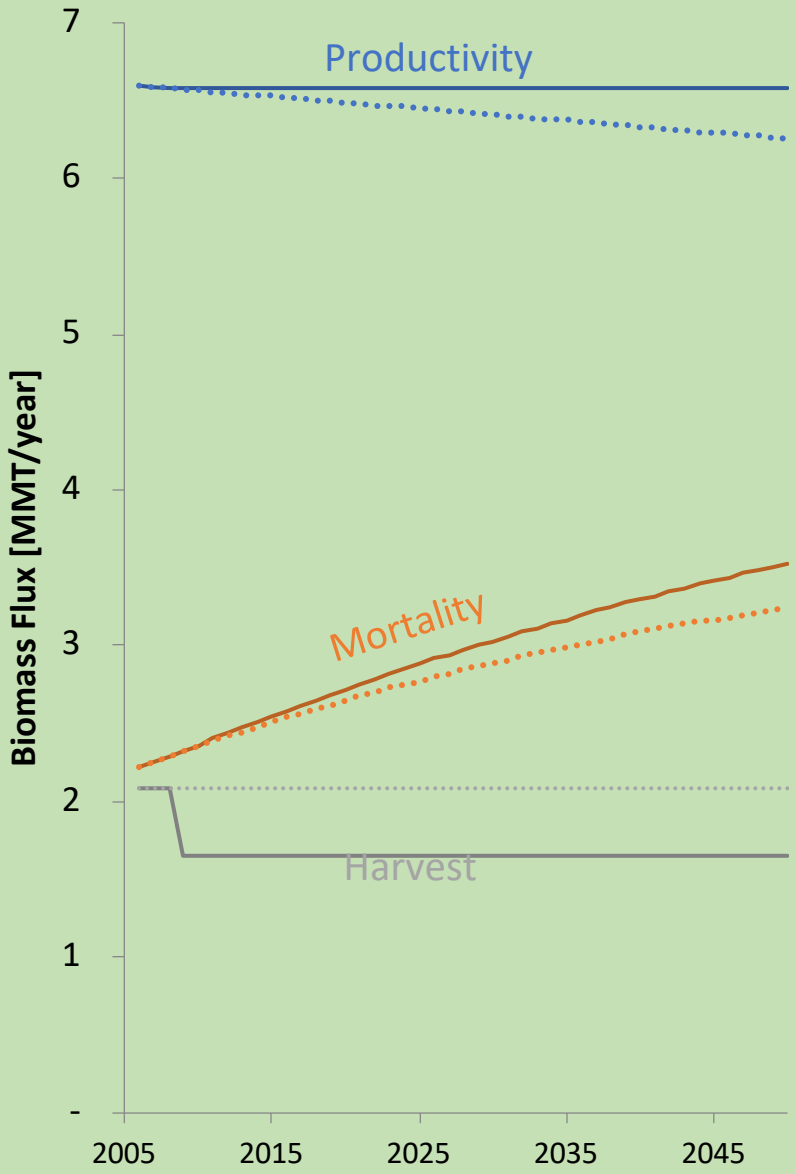


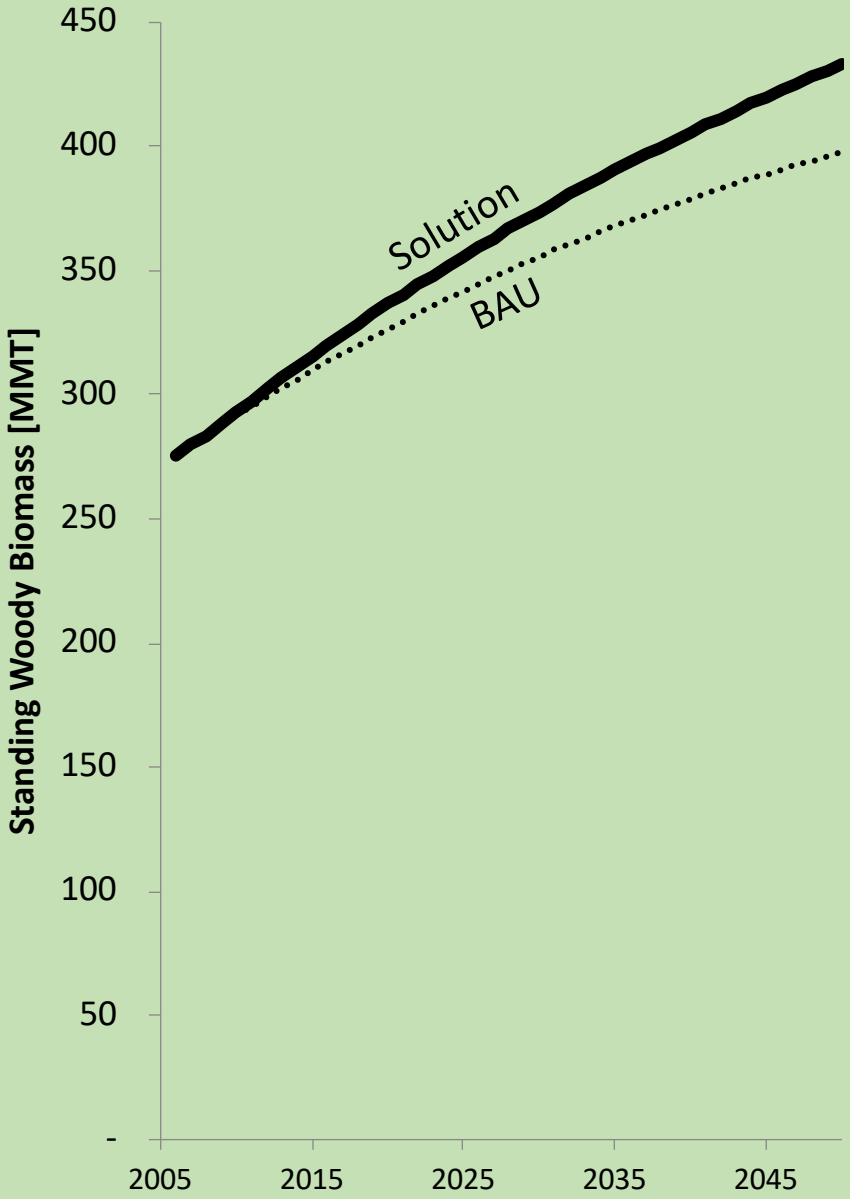
BAU


Biomass Flux [MMT/year]
7
6
5
4
3
2
1
-
2005
2015
2025
2035
2045
Productivity
Mortality
Harvest

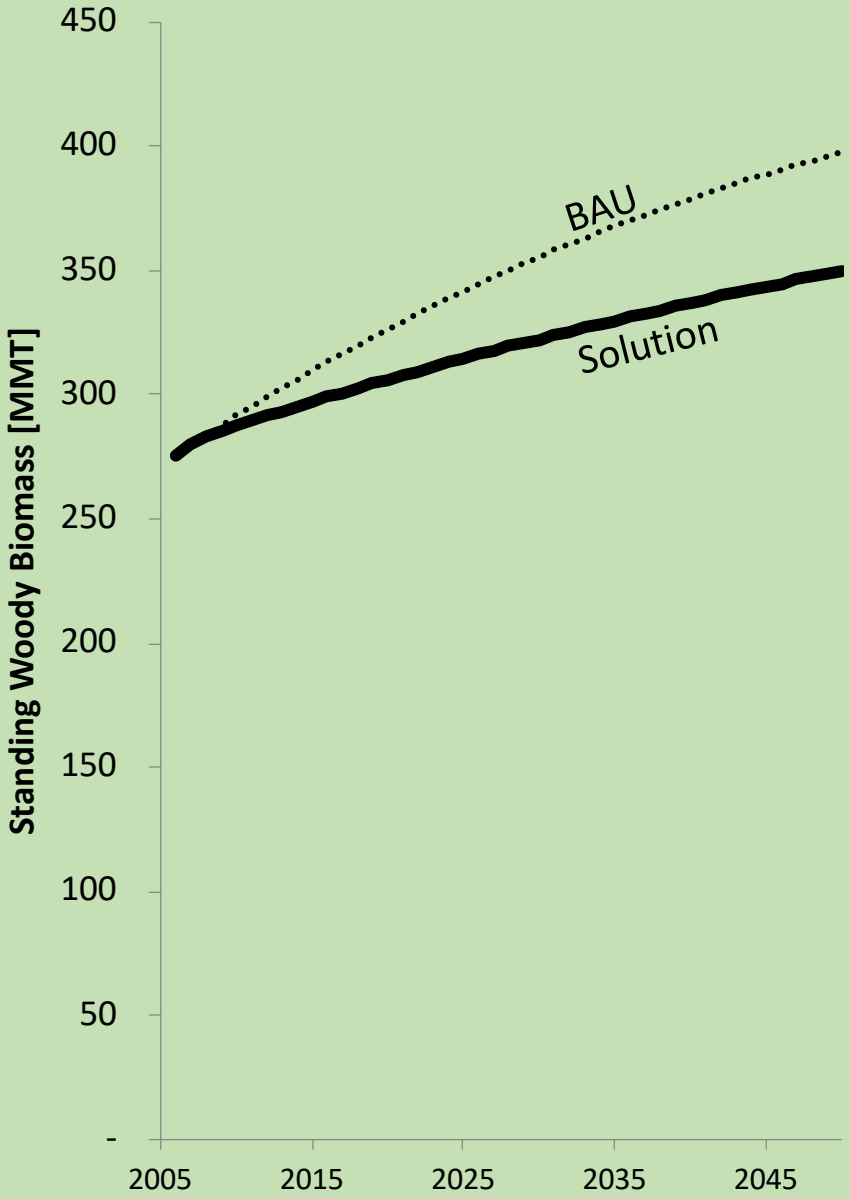

Standing Woody Biomass [MMT]
450
400
350
300
250
200
150
100
50
-
2005
2015
2025
2035
2045
Standing Stock

Avoid all forested land conversion

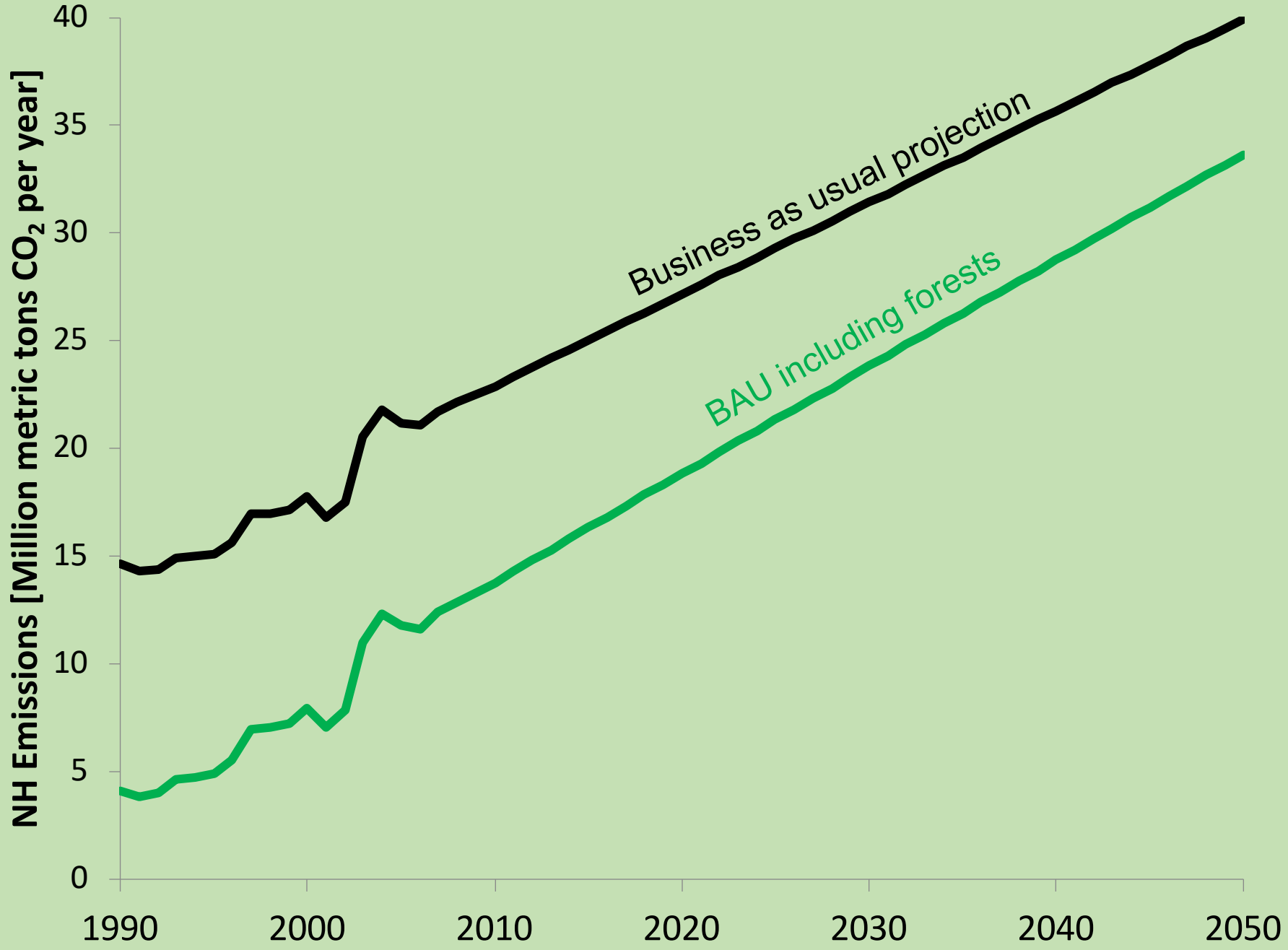




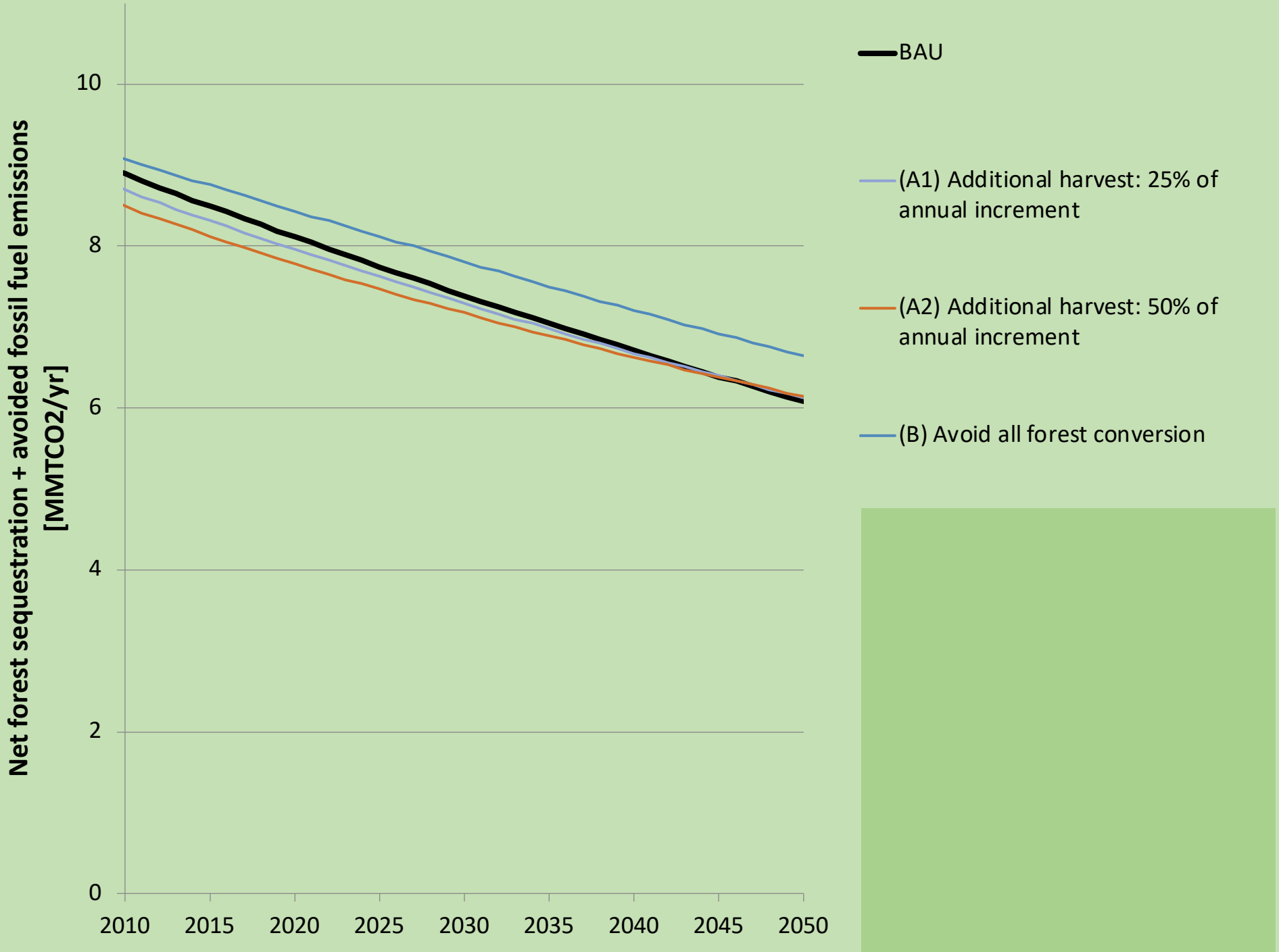
Additional annual harvest: 50% of increment

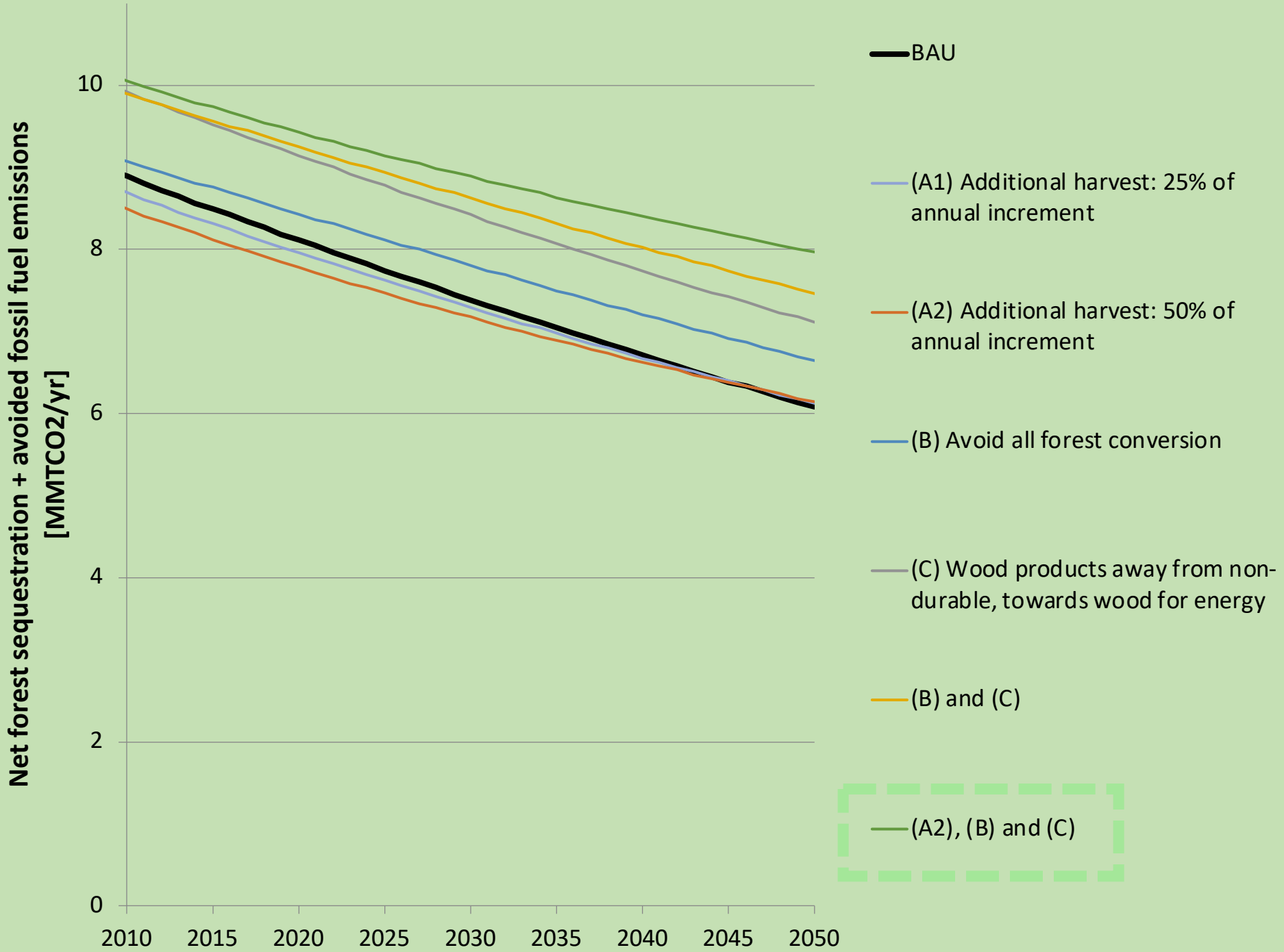



BAU
Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
2020
2025
2030
2035
2040
2045
2050


NH Emissions [Million metric tons CO_2 per year]
0
5
10
15
20
25
30
35
40
1990
2000
2010
2020
2030
2040
2050
Business as usual projection
BAU including forests


BAU
Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
2020
2025
2030
2035
2040
2045
2050


Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
2020
2025
2030
2035
2040
2045
2050
BAU
(A1) Additional harvest: 25% of annual increment
(A2) Additional harvest: 50% of annual increment
(B) Avoid all forest conversion


Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
2020
2025
2030
2035
2040
2045
2050
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(A1) Additional harvest: 25% of annual increment
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(C) Wood products away from non-durable, towards wood for energy
(B) and (C)
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Combination Scenario

Wood for electricity scenario

Wood electricity generation (MW capacity, wood/total)	**2002**	**2009**
Current	**89** / 1821	
Scenario estimate		**179** / 2733

Wood home heating (trillion BTU, wood/total)	**2005**	**2009**
Current	**2.7** / 54	
Scenario estimate		**9.8** / 54

Carbon savings [MMTCO2e]		
2012	**2025**	**2050**
1.25	1.45	1.91

Combination Scenario

Wood for home heating scenario

Wood electricity generation (MW capacity, wood/total)	**2002**	**2009**
Current	**89** / 1821	
Scenario estimate		**0** / 2733

Wood home heating (trillion BTU, wood/total)	**2005**	**2009**
Current	**2.7** / 54	
Scenario estimate		**29.2** / 54

Carbon savings [MMTCO2e]		
2012	**2025**	**2050**
2.01	2.18	2.59

Combination Scenario

50/50 scenario

Wood electricity generation (MW capacity, wood/total)	**2002**	**2009**
Current	**89** / 1821	
Scenario estimate		**87** / 2733

Wood home heating (trillion BTU, wood/total)	**2005**	**2009**
Current	**2.7** / 54	
Scenario estimate		**19.5** / 54

Carbon savings [MMTCO2e]		
2012	**2025**	**2050**
1.63	1.81	2.25

Forestry Recommendations
Key Concepts

- Sustainably managed forests in New Hampshire forests provide a broad range of ecosystem goods and services ("ecosystem services") to New Hampshire including:
  - carbon sequestration and storage;
  - biomass for a variety of forest products;
  - ecological functions; and
  - various recreational opportunities.
- Increasing the rate of timber harvest without changing wood use or forested land loss reduces the rate of carbon sequestration and total carbon storage in the short-term and leads to a higher sequestration rate over the long-term.

Forestry Recommendations
Key Concepts

- Reallocating non-durable grade wood to biomass energy (e.g., electric generation, heating) results in a significant positive carbon benefit.
- Sustainably managed forests possess a significant economic development potential.
- The maintenance of working forests is an essential mechanism to provide value to forested lands and avoid forested land conversion.

Forestry Recommendations
Key Potential Recommendations

- Maximize the avoidance of existing forested land loss and eliminate the net loss of forested land.
  - Preserve/maintain working forests.
  - Adopt land use and transportation planning that maintains the traditional settlement patterns in cities and towns.
- Adopt sustainable forest management techniques that maximize harvested tree size.
  - (*Potentially*) Maximize Forest Stewardship Council certification in the state.
- Biomass energy can provide a resource that complements expanded energy efficiency and energy conservation programs and generation by other forms of renewables.

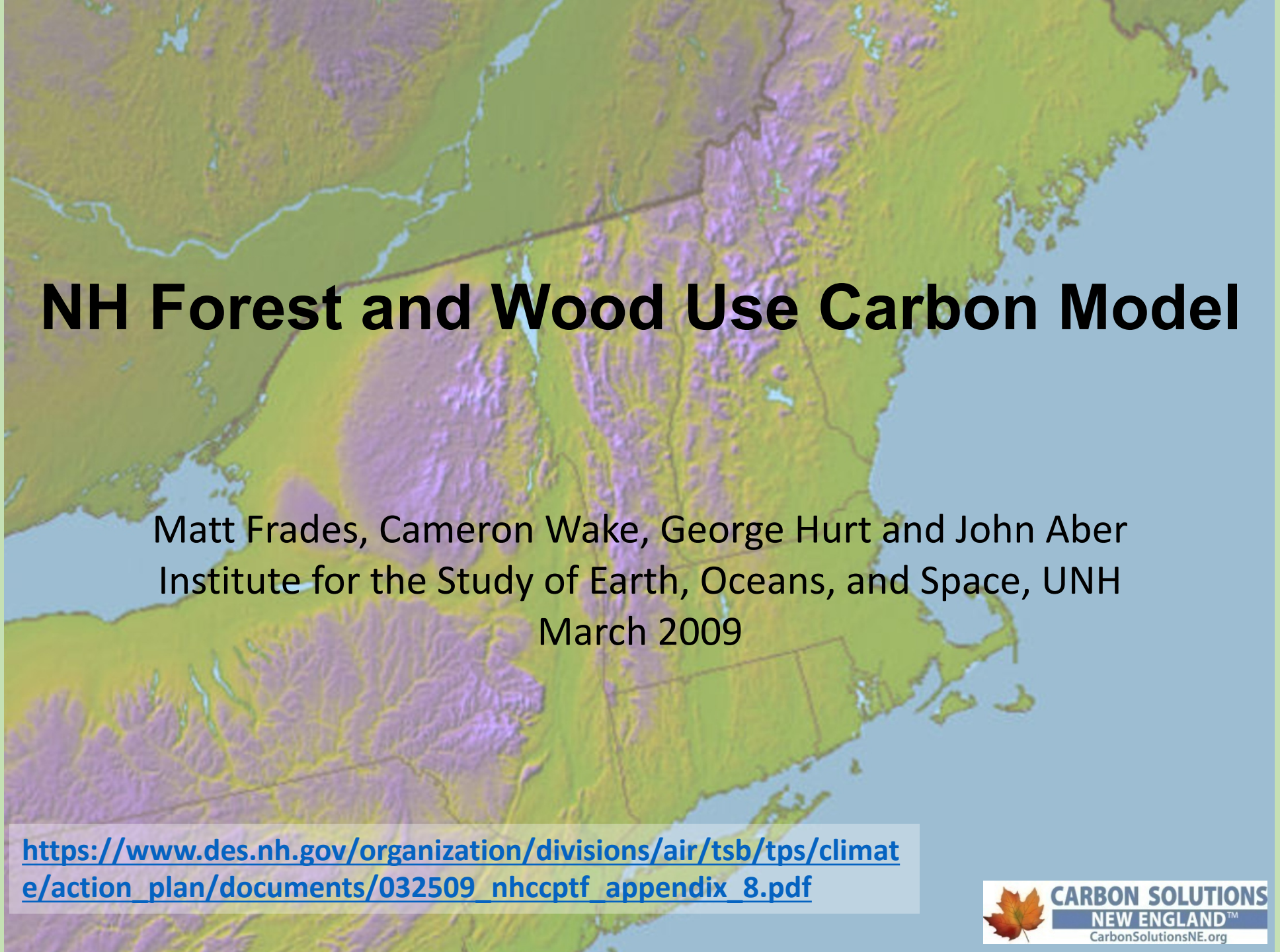
Forestry Recommendations
Key Potential Recommendations

- Promote wood for energy to the extent that it displaces fossil fuel consumption and promotes economic development.
  - Direct biomass to the best and highest use for energy.
  - Direct early cull to energy.
  - Maximize the energy that can be generated from forest products industry waste.
- Develop alternative and stable funding mechanisms, including potential RGGI Funds, to support the protection of working forests.
- Develop mechanisms to fully value forest ecosystem services and to compensate landowners for the maintenance of those services.

Contact

Chris Skoglund
Climate and Energy Program Manager
NH Department of Environmental Services
Christopher.skoglund@des.nh.gov
(603) 271-7624

Full Slide Deck for Reference



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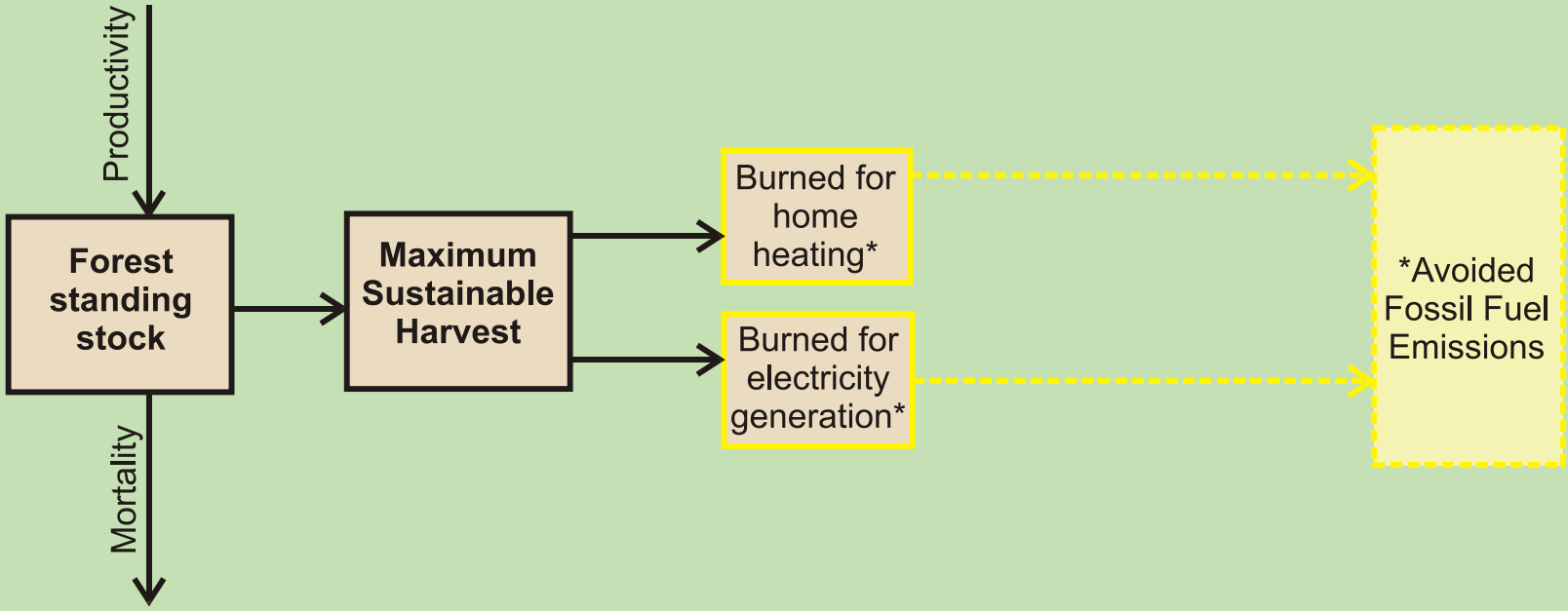

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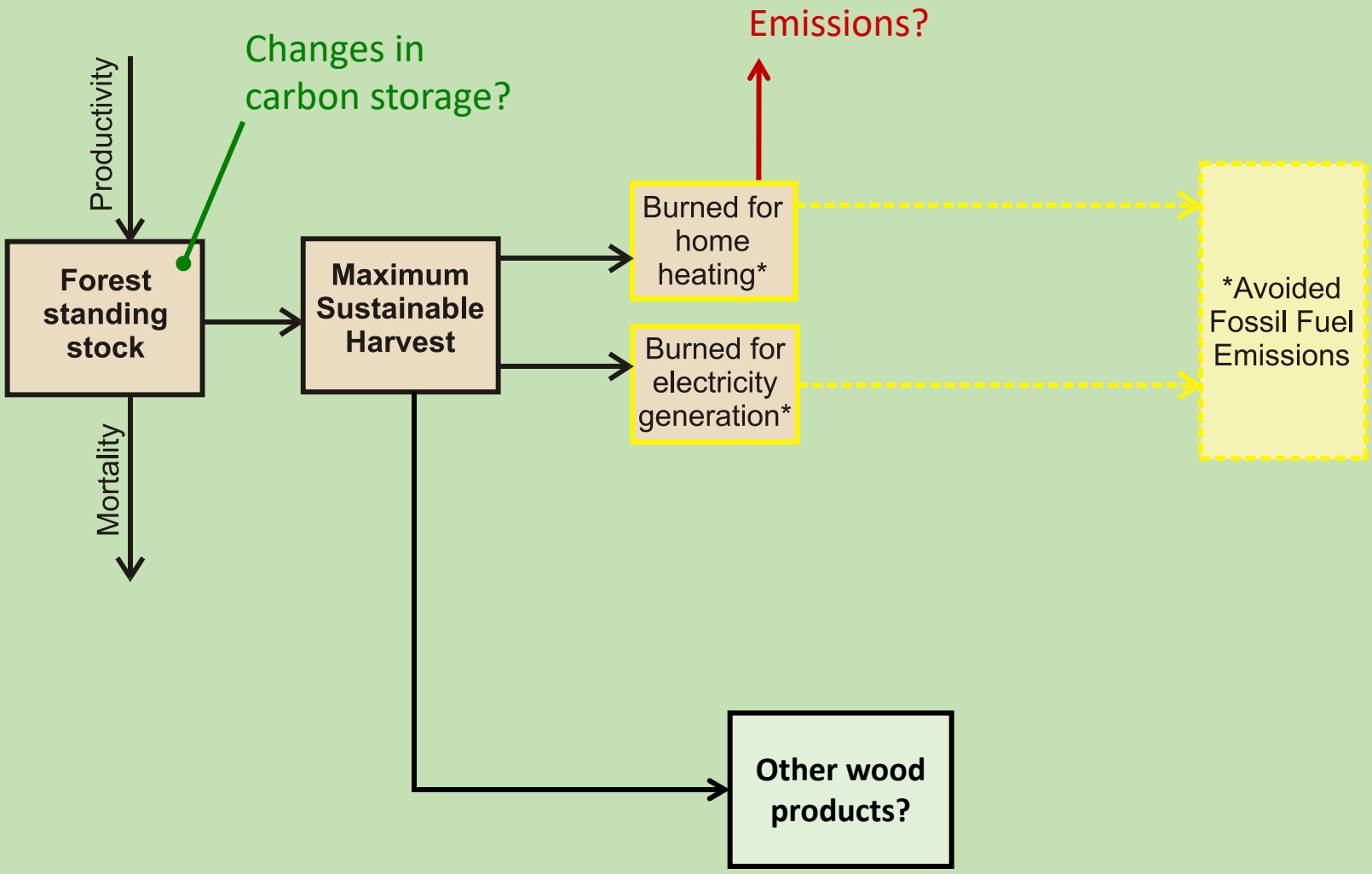

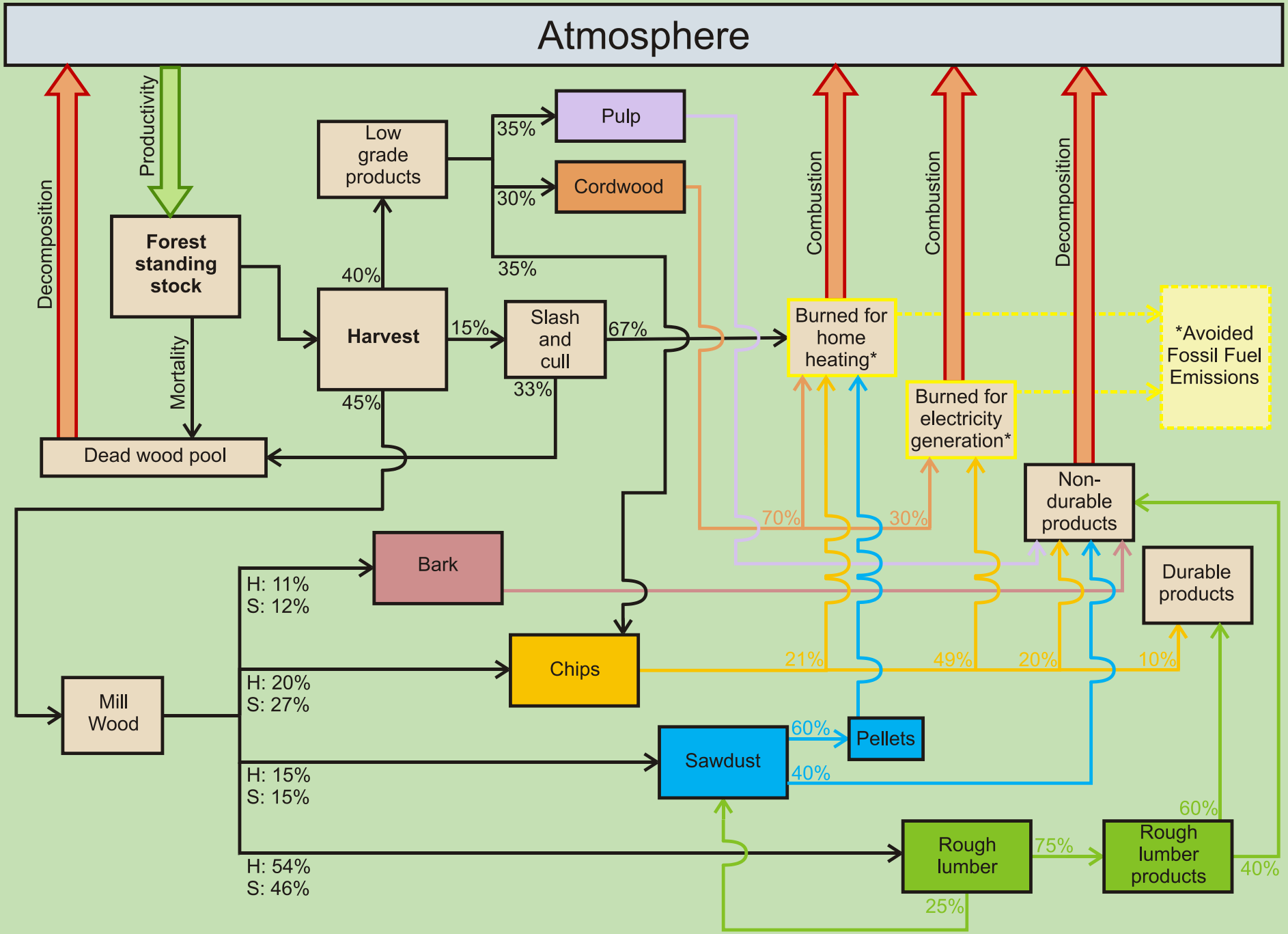
Atmosphere
Decomposition
Productivity
Forest standing stock
Mortality
Dead wood pool
Low grade products
40%
Harvest
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33%
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30%
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H: 11%
S: 12%
Chips
21%
49%
20%
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Mill Wood
H: 20%
S: 27%
H: 15%
S: 15%
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Sawdust
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Pellets
40%
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Rough lumber products
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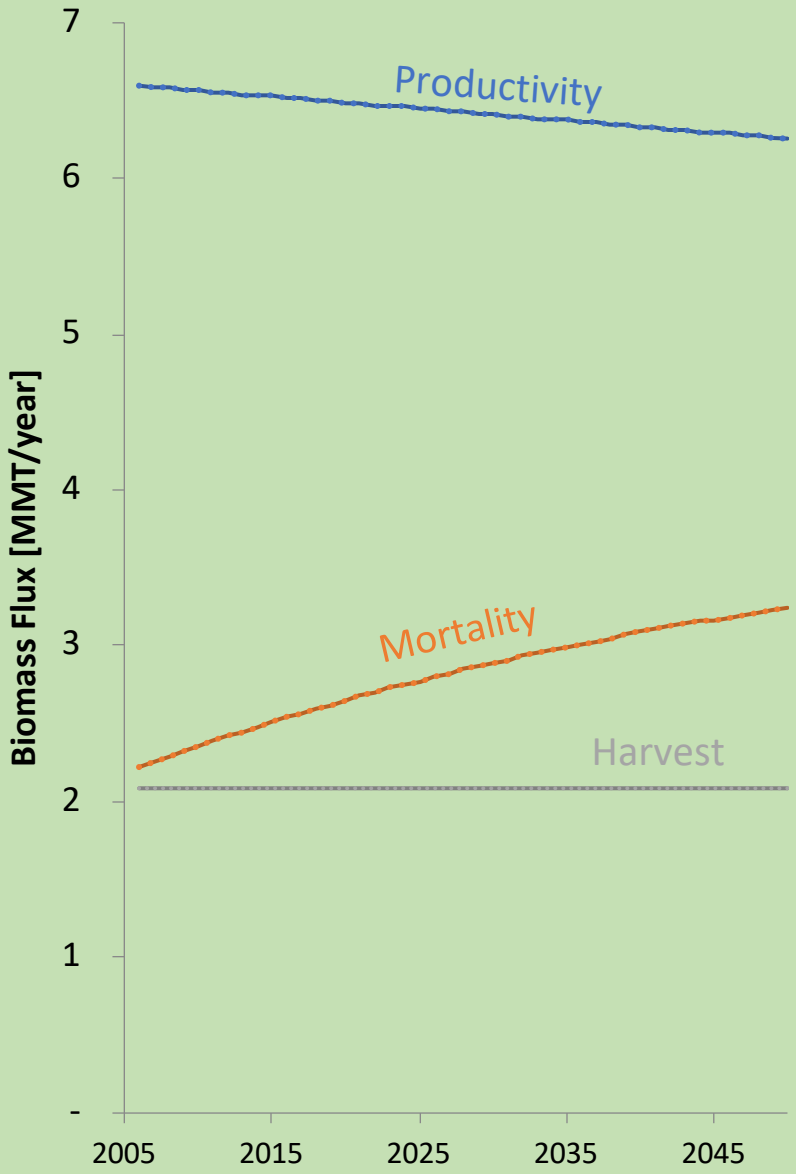
25%

BAU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2025
2035
2045
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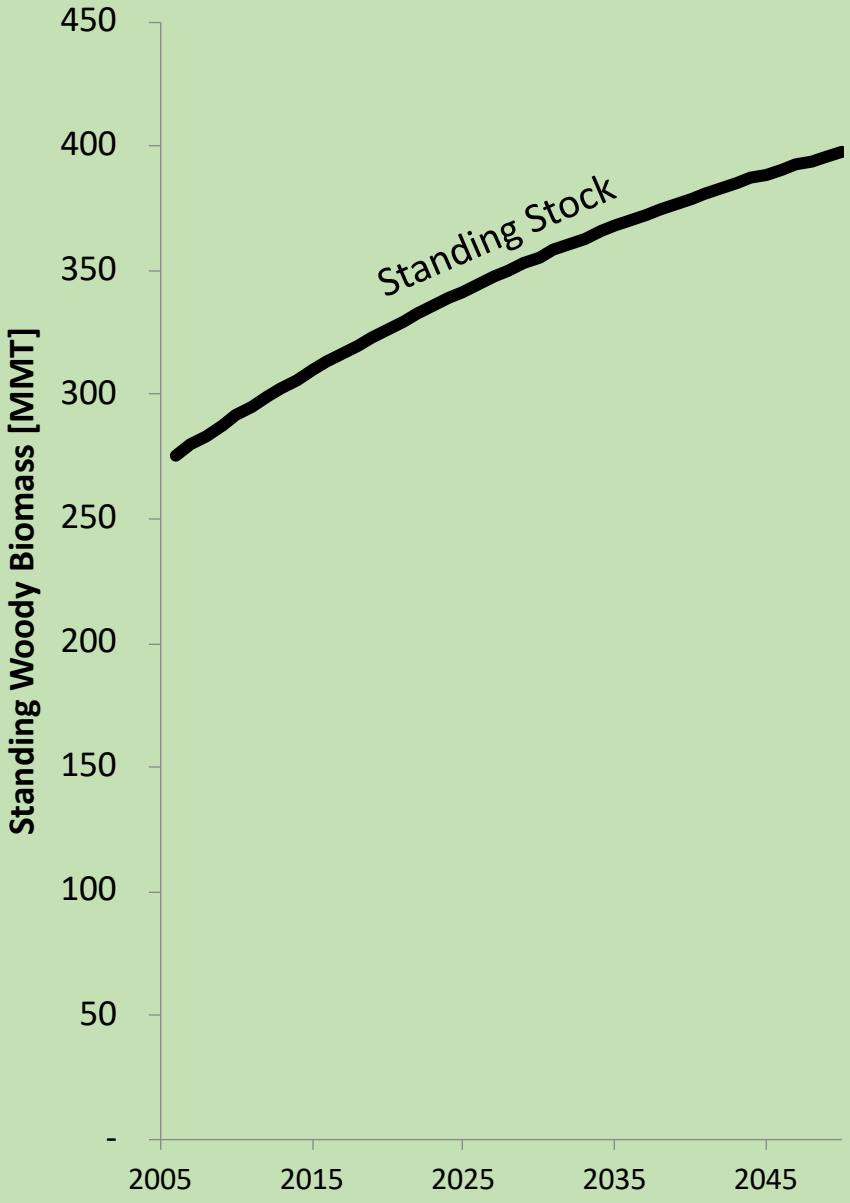
Mortality
Harvest


Standing Woody Biomass [MMT]
450
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250
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150
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50
-
2005
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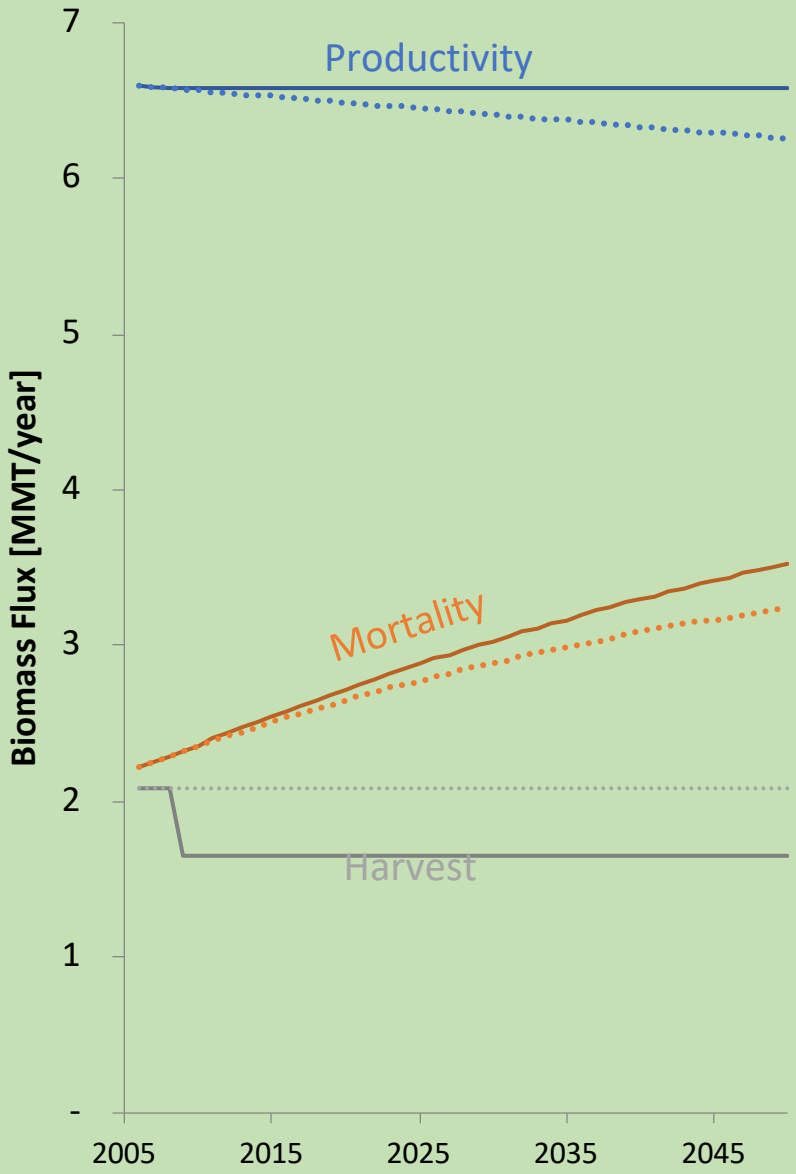
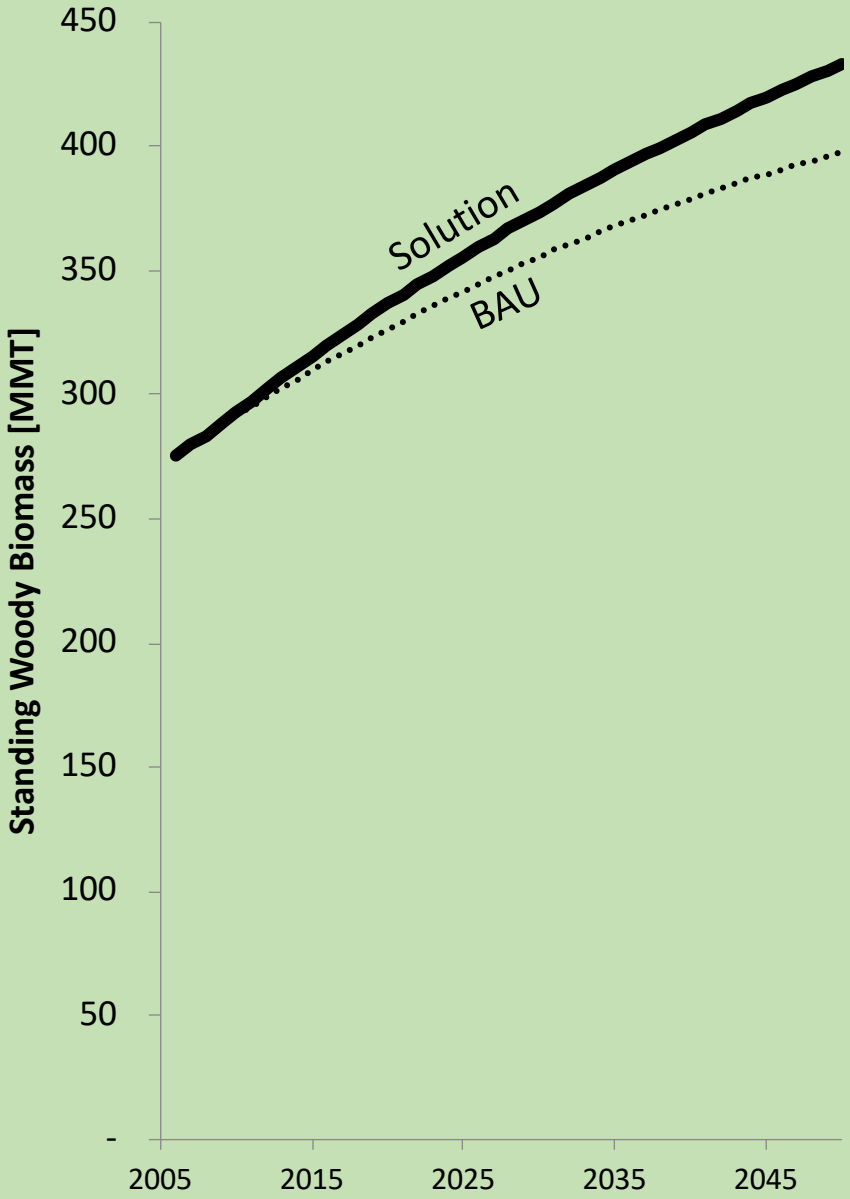
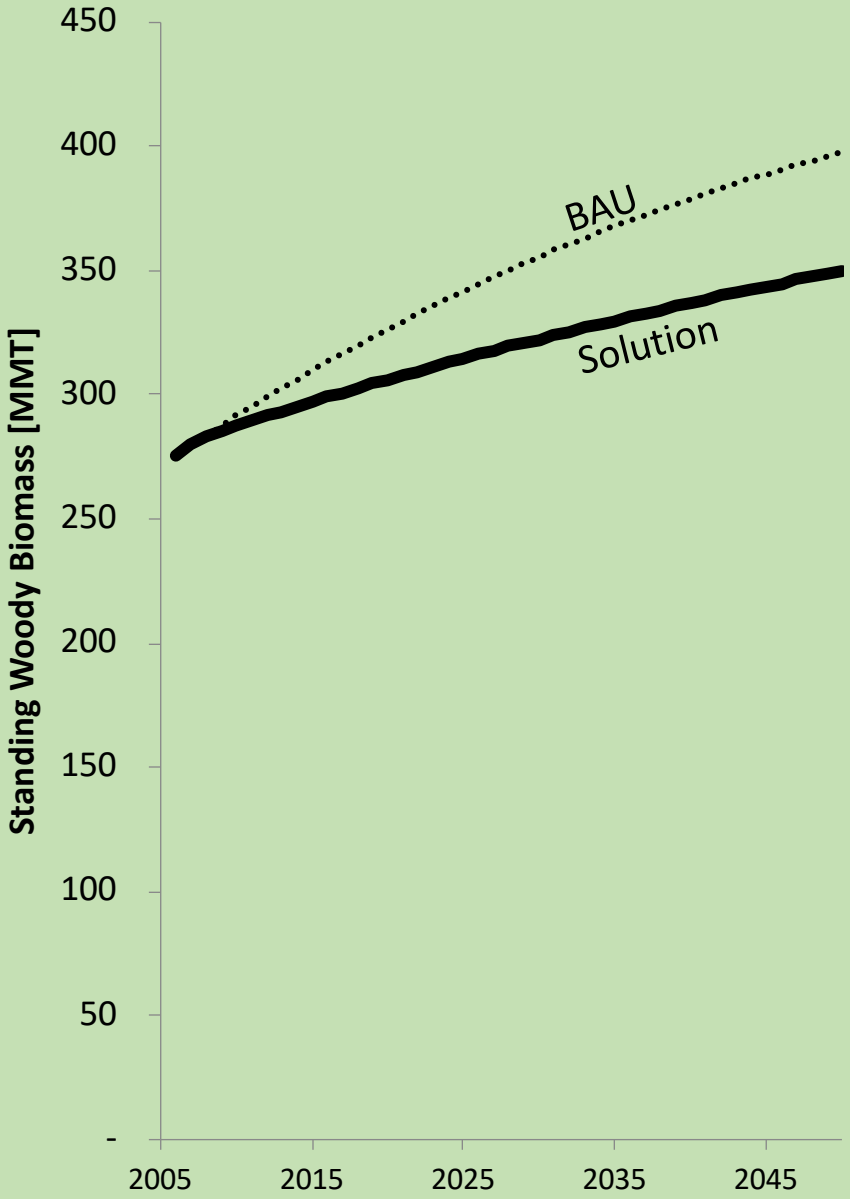
2025
2035
2045
Standing Stock

Avoid all forested land conversion

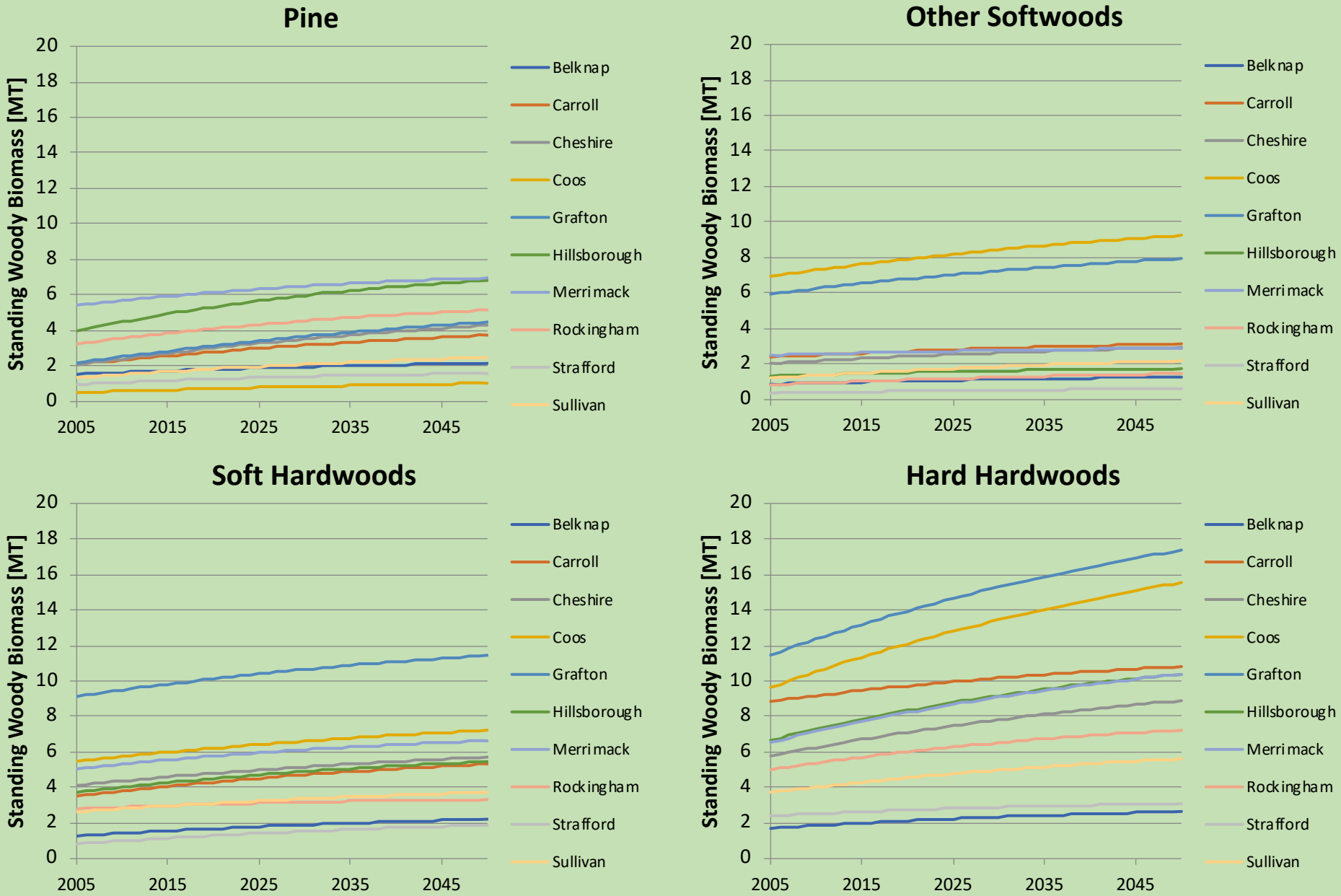


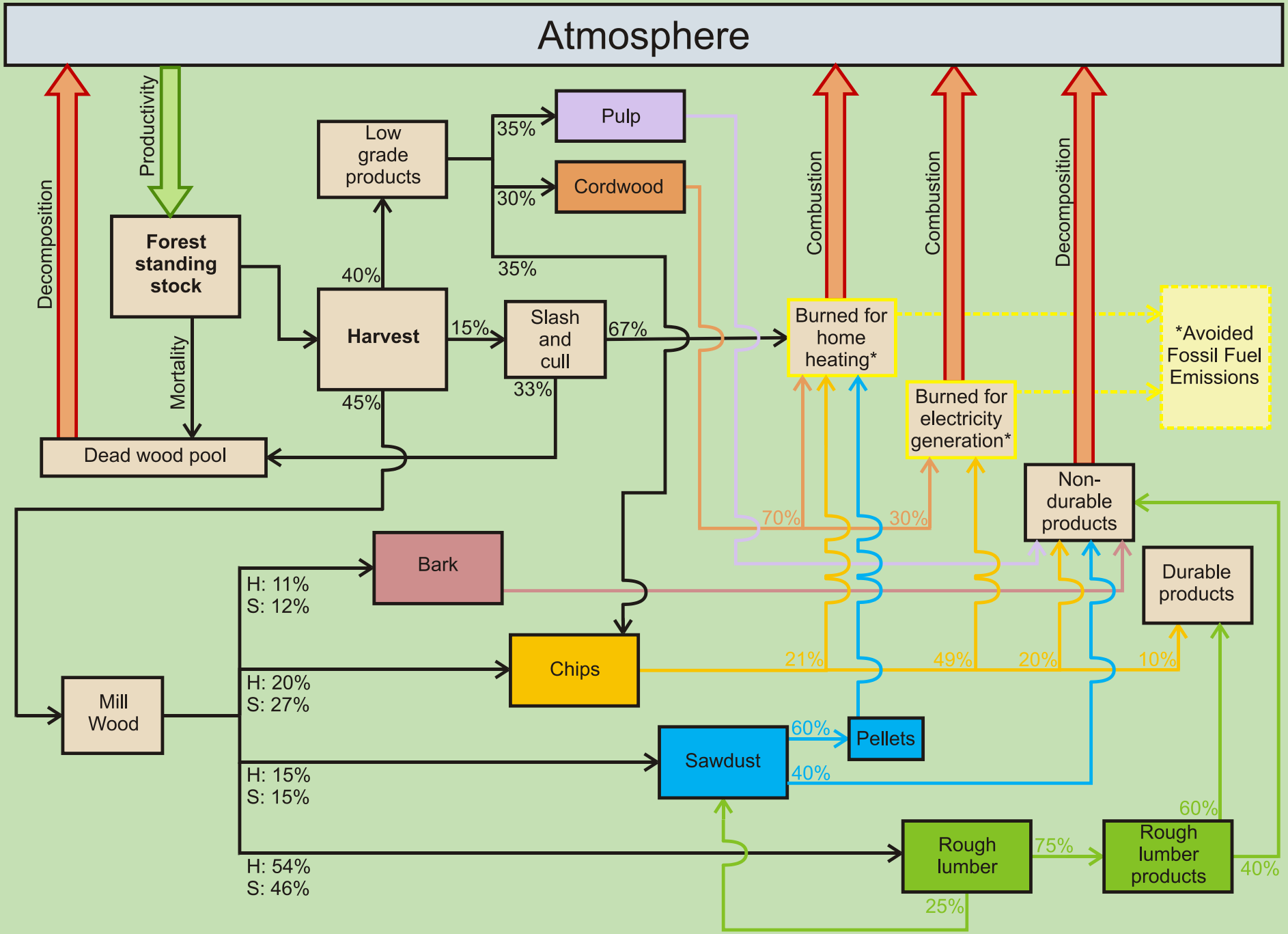


Additional annual harvest: 50% of increment



Model Output (BAU): Standing Woody Biomass
(10 counties, 4 Forest Classes)

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Burned for home heating*
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Mill Wood
H: 20%
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H: 15%
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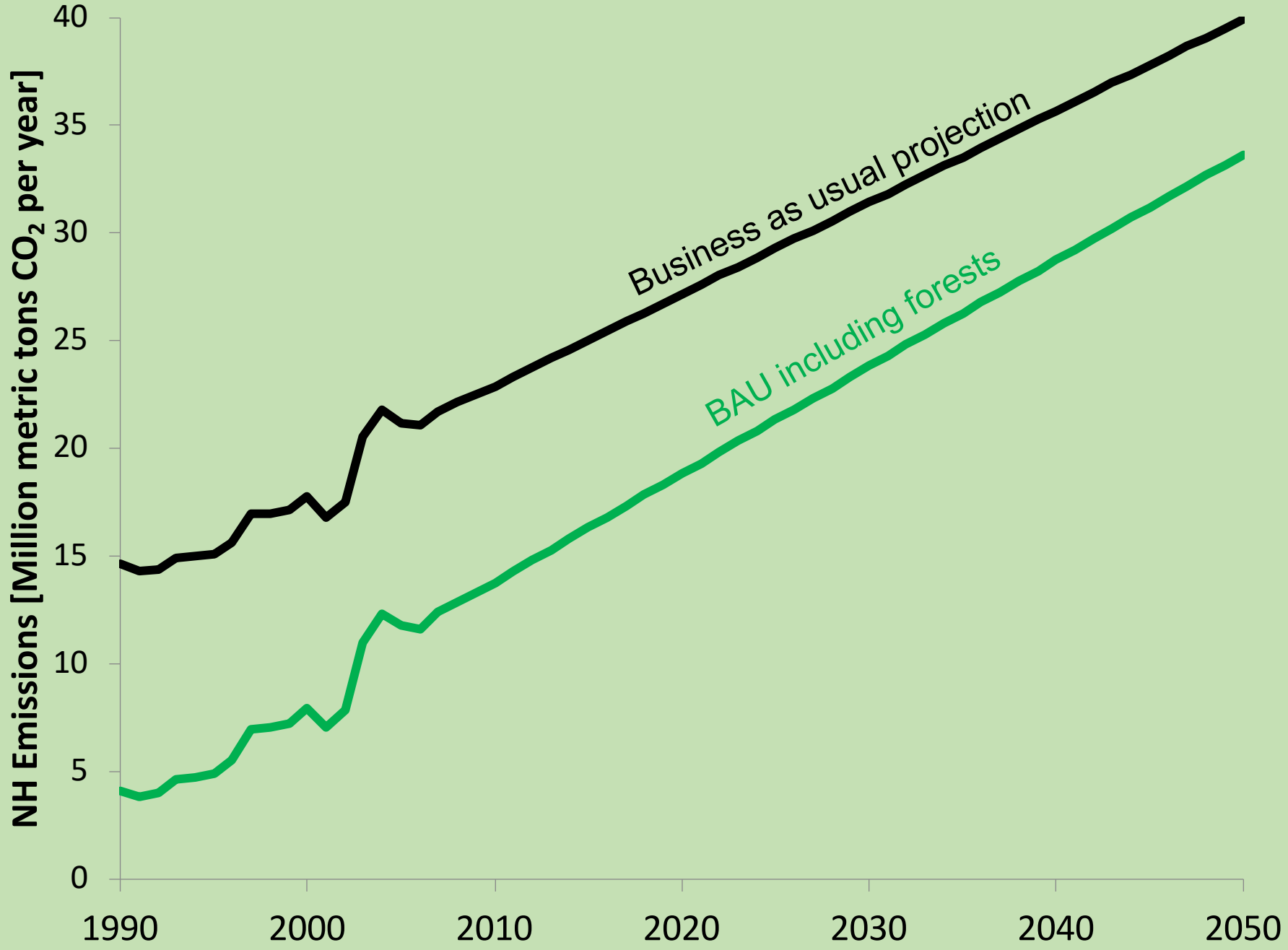
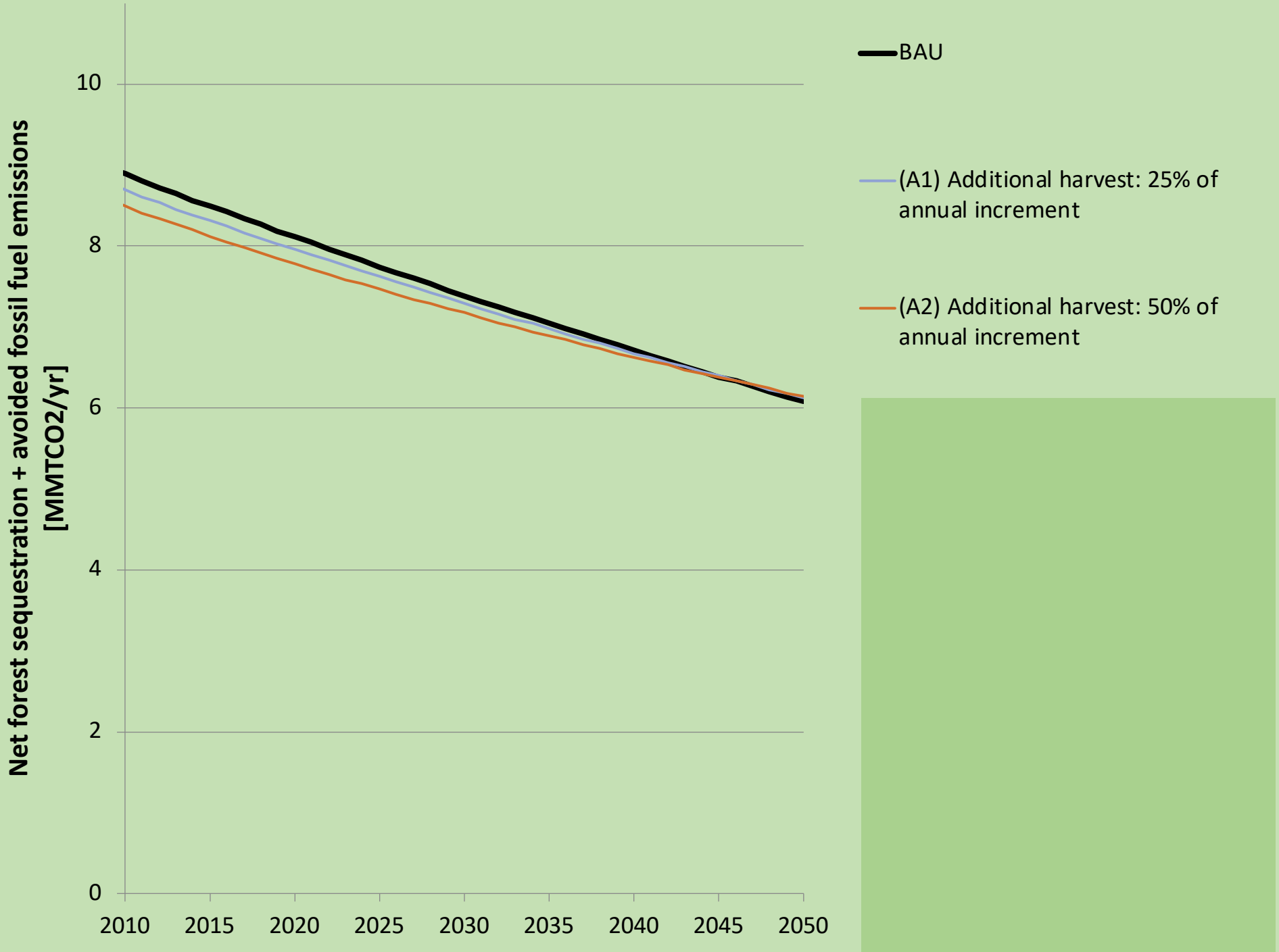
H: 54%
S: 46%
Sawdust
60%
Pellets
40%
Rough lumber
75%
Rough lumber products
60%
40%
25%


BAU
Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
2020
2025
2030
2035
2040
2045
2050


NH Emissions [Million metric tons CO_2 per year]
0
5
10
15
20
25
30
35
40
1990
2000
2010
2020
2030
2040
2050
Business as usual projection
BAU including forests


BAU
Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
2020
2025
2030
2035
2040
2045
2050


Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
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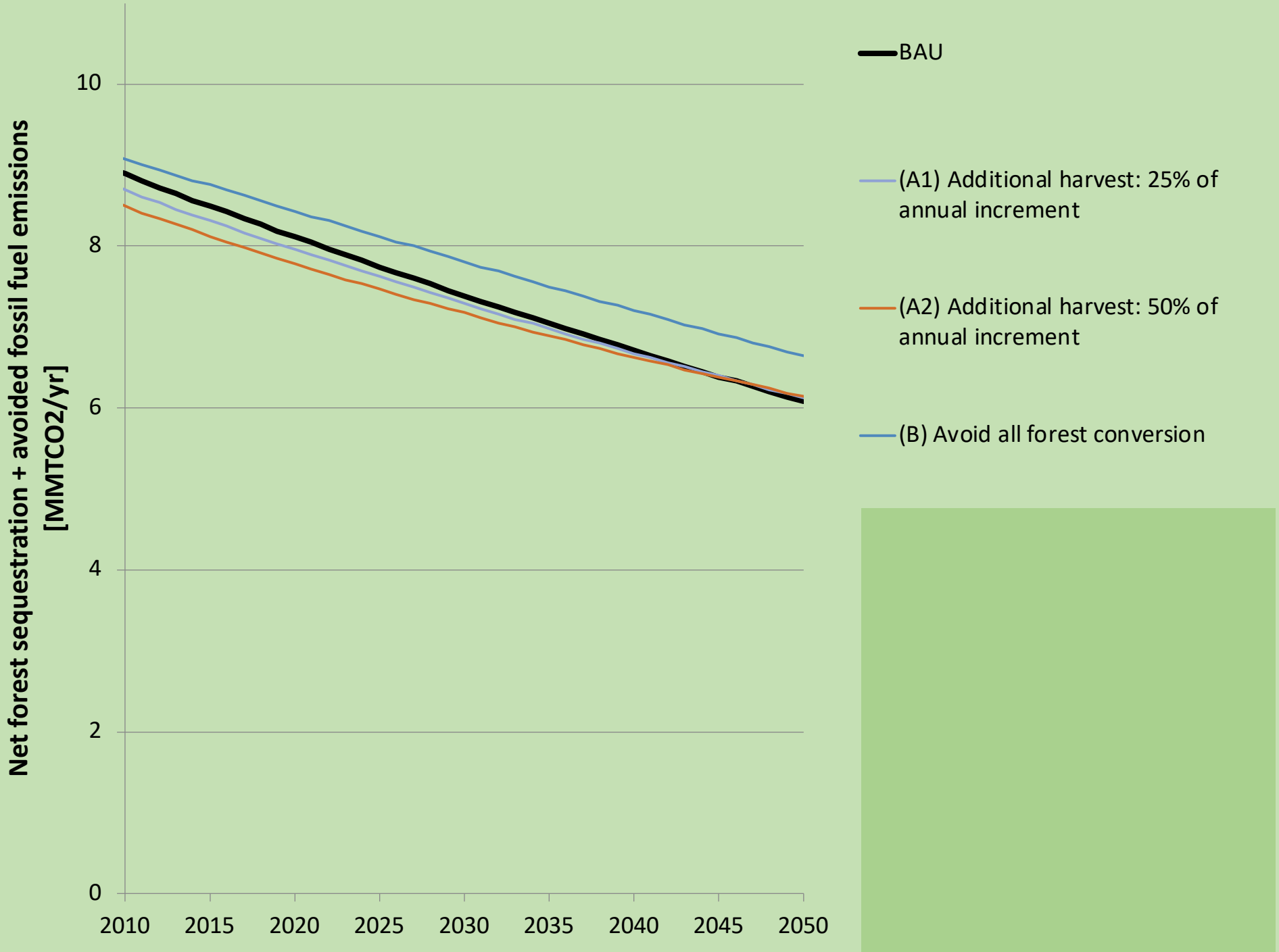
2025
2030
2035
2040
2045
2050
BAU
(A1) Additional harvest: 25% of annual increment
(A2) Additional harvest: 50% of annual increment


Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
2020
2025
2030
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2040
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2050
BAU
(A1) Additional harvest: 25% of annual increment
(A2) Additional harvest: 50% of annual increment
(B) Avoid all forest conversion


Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
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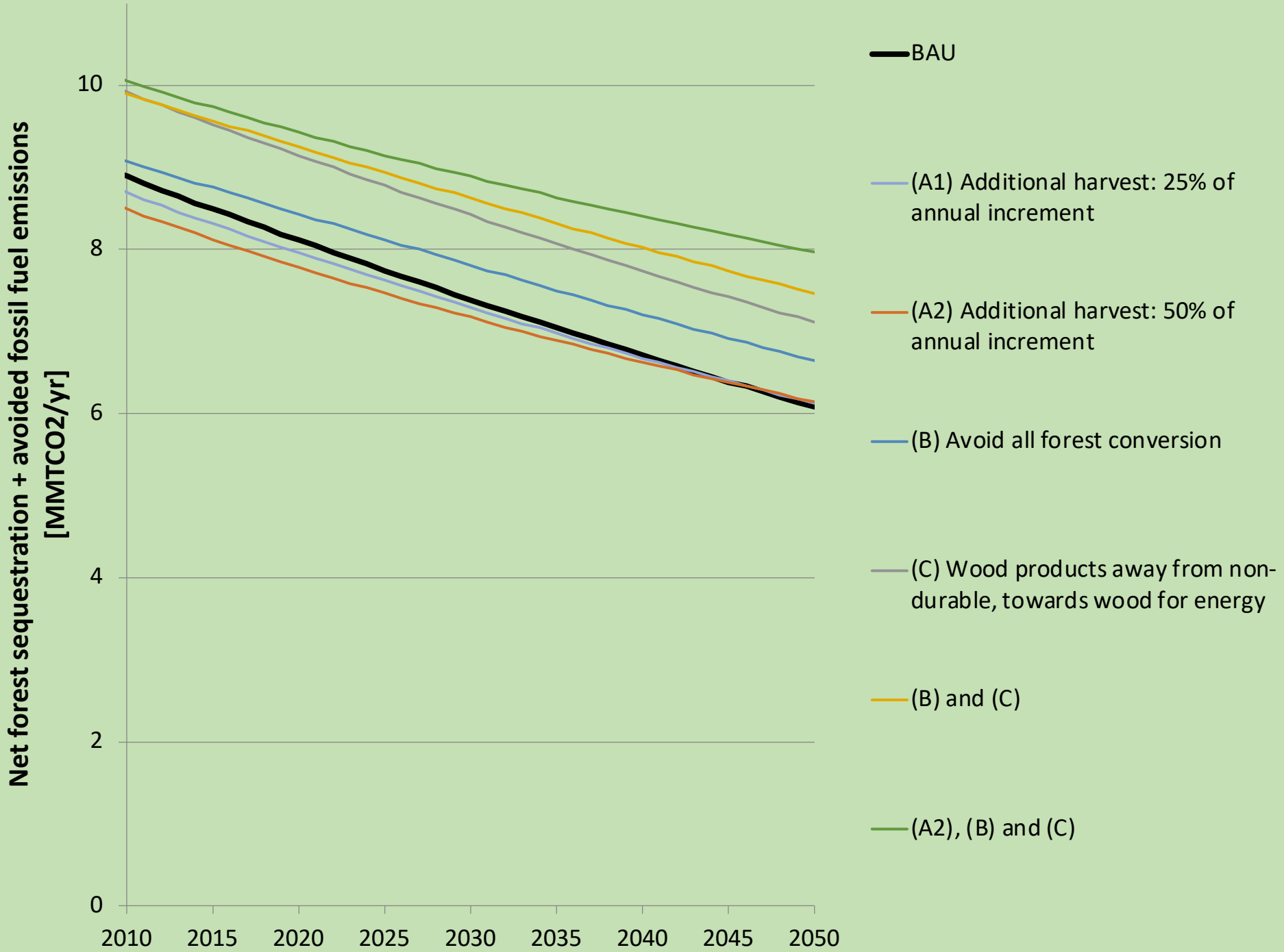
Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
8
6
4
2
0
2010
2015
2020
2025
2030
2035
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2045
2050
BAU
(A1) Additional harvest: 25% of annual increment
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(B) Avoid all forest conversion
(C) Wood products away from non-durable, towards wood for energy
(B) and (C)
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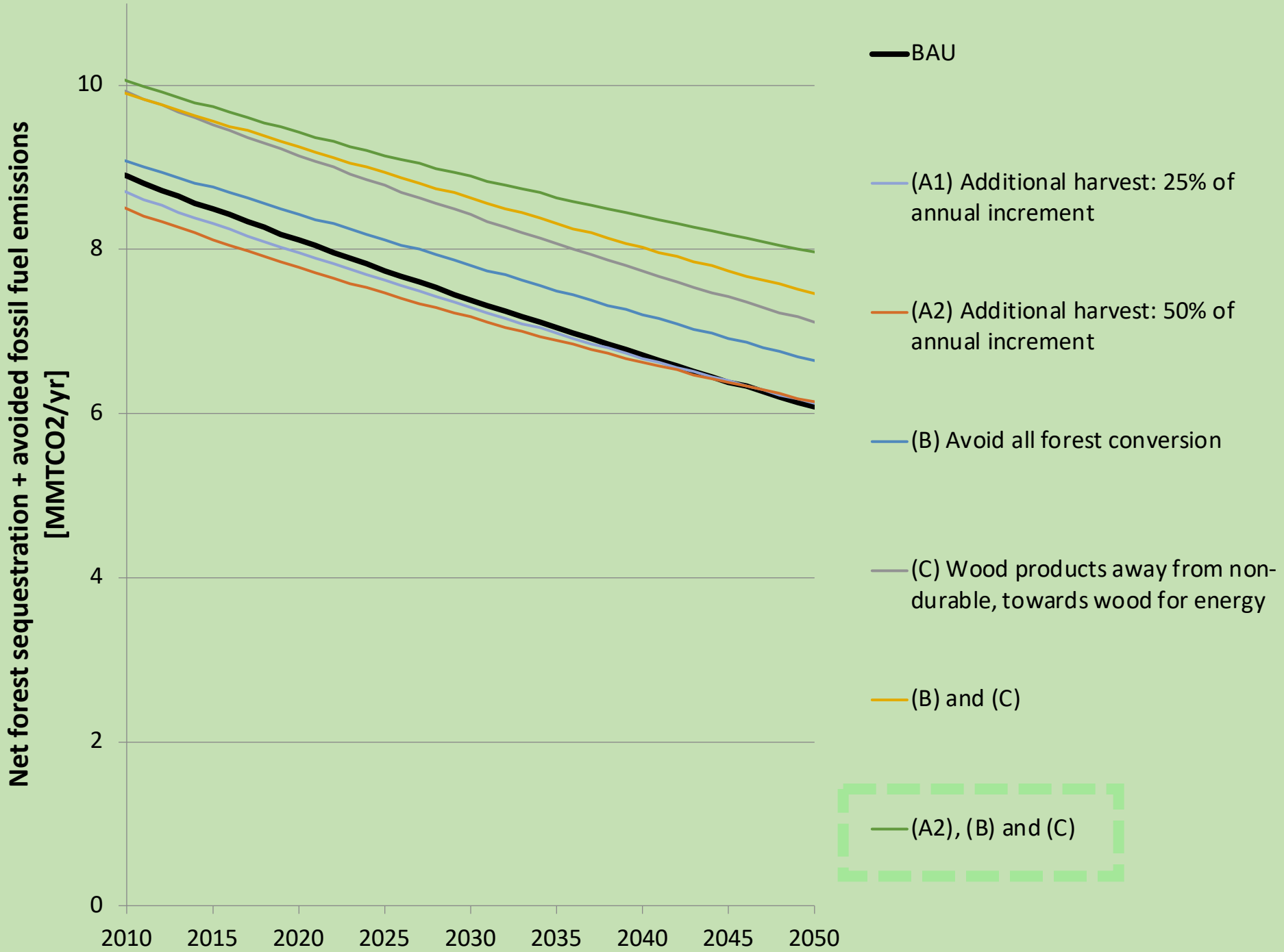
Net forest sequestration + avoided fossil fuel emissions [MMTCO2/yr]
10
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2030
2035
2040
2045
2050
BAU
(A1) Additional harvest: 25% of annual increment
(A2) Additional harvest: 50% of annual increment
(B) Avoid all forest conversion
(C) Wood products away from non-durable, towards wood for energy
(B) and (C)
(A2), (B) and (C)

Combination Scenario

Wood for electricity scenario

Wood electricity generation (MW capacity, wood/total)	**2002**	**2009**
Current	**89** / 1821	
Scenario estimate		**179** / 2733

Wood home heating (trillion BTU, wood/total)	**2005**	**2009**
Current	**2.7** / 54	
Scenario estimate		**9.8** / 54

Carbon savings [MMTCO2e]		
2012	**2025**	**2050**
1.25	1.45	1.91

Combination Scenario

Wood for home heating scenario

Wood electricity generation (MW capacity, wood/total)	**2002**	**2009**
Current	**89** / 1821	
Scenario estimate		**0** / 2733

Wood home heating (trillion BTU, wood/total)	**2005**	**2009**
Current	**2.7** / 54	
Scenario estimate		**29.2** / 54

Carbon savings [MMTCO2e]		
2012	**2025**	**2050**
2.01	2.18	2.59

Combination Scenario

50/50 scenario

Wood electricity generation (MW capacity, wood/total)	**2002**	**2009**
Current	**89** / 1821	
Scenario estimate		**87** / 2733

Wood home heating (trillion BTU, wood/total)	**2005**	**2009**
Current	**2.7** / 54	
Scenario estimate		**19.5** / 54

Carbon savings [MMTCO2e]		
2012	**2025**	**2050**
1.63	1.81	2.25

Forestry Recommendations
Key Concepts

- Sustainably managed forests in New Hampshire forests provide a broad range of ecosystem goods and services ("ecosystem services") to New Hampshire including:
  - carbon sequestration and storage;
  - biomass for a variety of forest products;
  - ecological functions; and
  - various recreational opportunities.
- Increasing the rate of timber harvest without changing wood use or forested land loss reduces the rate of carbon sequestration and total carbon storage in the short-term and leads to a higher sequestration rate over the long-term.

Forestry Recommendations
Key Concepts

- Reallocating non-durable grade wood to biomass energy (e.g., electric generation, heating) results in a significant positive carbon benefit.
- Sustainably managed forests possess a significant economic development potential.
- The maintenance of working forests is an essential mechanism to provide value to forested lands and avoid forested land conversion.

Forestry Recommendations
Key Potential Recommendations

- Maximize the avoidance of existing forested land loss and eliminate the net loss of forested land.
  - Preserve/maintain working forests.
  - Adopt land use and transportation planning that maintains the traditional settlement patterns in cities and towns.
- Adopt sustainable forest management techniques that maximize harvested tree size.
  - (*Potentially*) Maximize Forest Stewardship Council certification in the state.
- Biomass energy can provide a resource that complements expanded energy efficiency and energy conservation programs and generation by other forms of renewables.

Forestry Recommendations
Key Potential Recommendations

- Promote wood for energy to the extent that it displaces fossil fuel consumption and promotes economic development.
  - Direct biomass to the best and highest use for energy.
  - Direct early cull to energy.
  - Maximize the energy that can be generated from forest products industry waste.
- Develop alternative and stable funding mechanisms, including potential RGGI Funds, to support the protection of working forests.
- Develop mechanisms to fully value forest ecosystem services and to compensate landowners for the maintenance of those services.

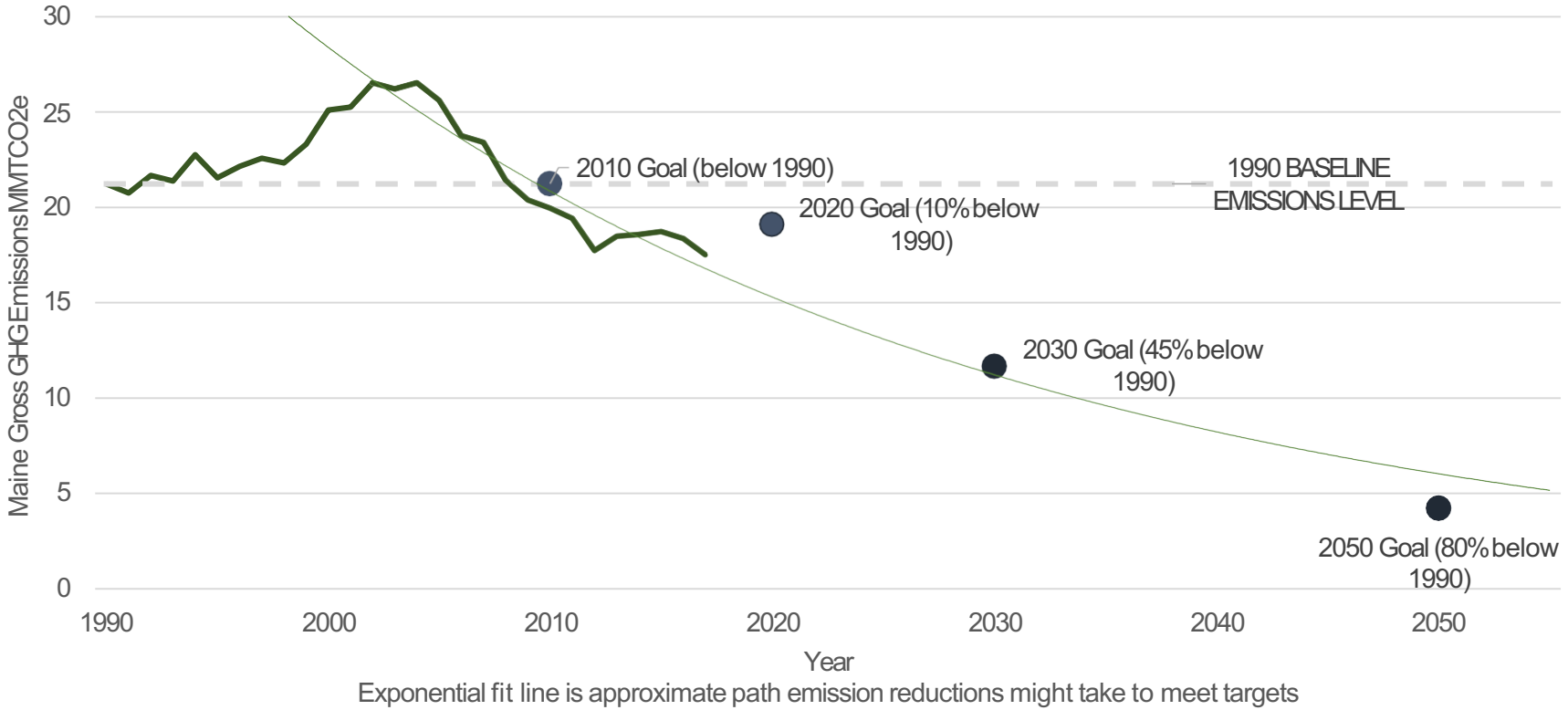
Climate Planning in Maine and Opportunities in Our Natural and Working Lands

Nathan Robbins
Climate Change Specialist
Climate and Adaptation Program
Commissioner's Office

A CLIMATE ACTION PLAN FOR MAINE

PL 2003 c. 237 ME DEP to develop Climate Action Plan (mitigate)

PL 2019 c. 476 ME Climate Council to develop Climate Action Plan (mitigate, prepare, adapt)

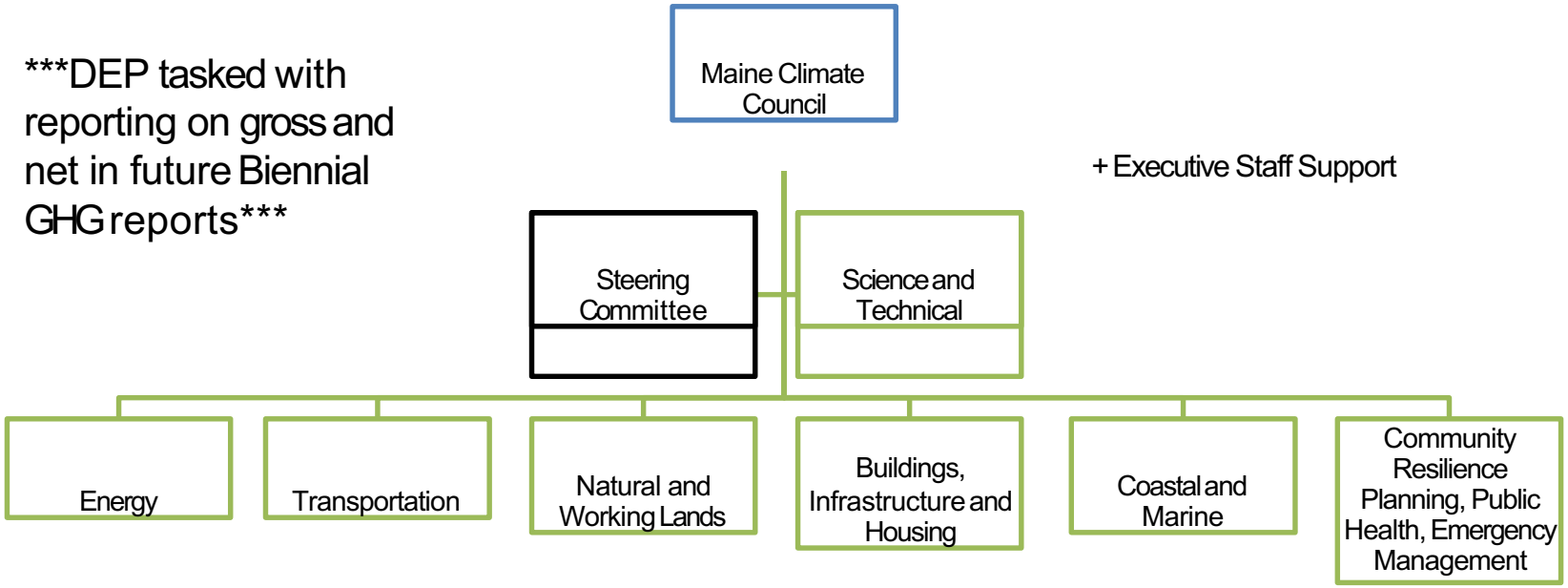


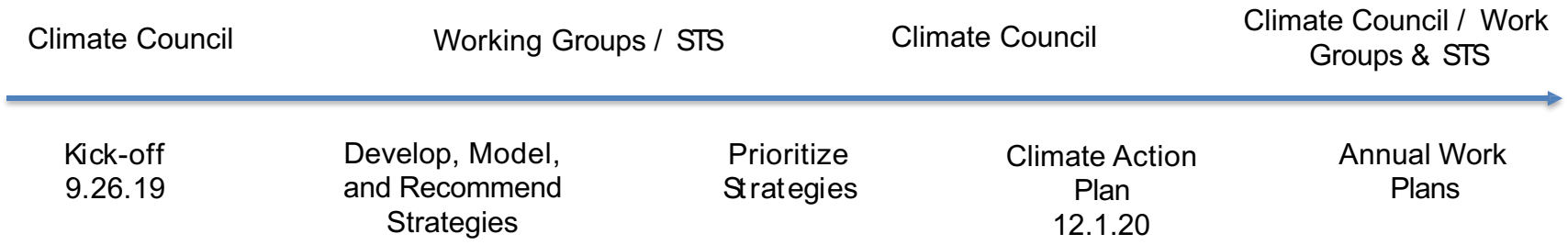
Maine Gross GHG emissions 1990-2017 ($MMTCO_2e$)

Source: Maine DEP 8th Biennial Report on Progress Toward GHG Reduction Goals 1/2020

MAINE CLIMATE COUNCIL LD 1679 | PL 2019 c. 476

DEP tasked with reporting on gross and net in future Biennial GHG reports





< Public Engagement & Comment Opportunities >

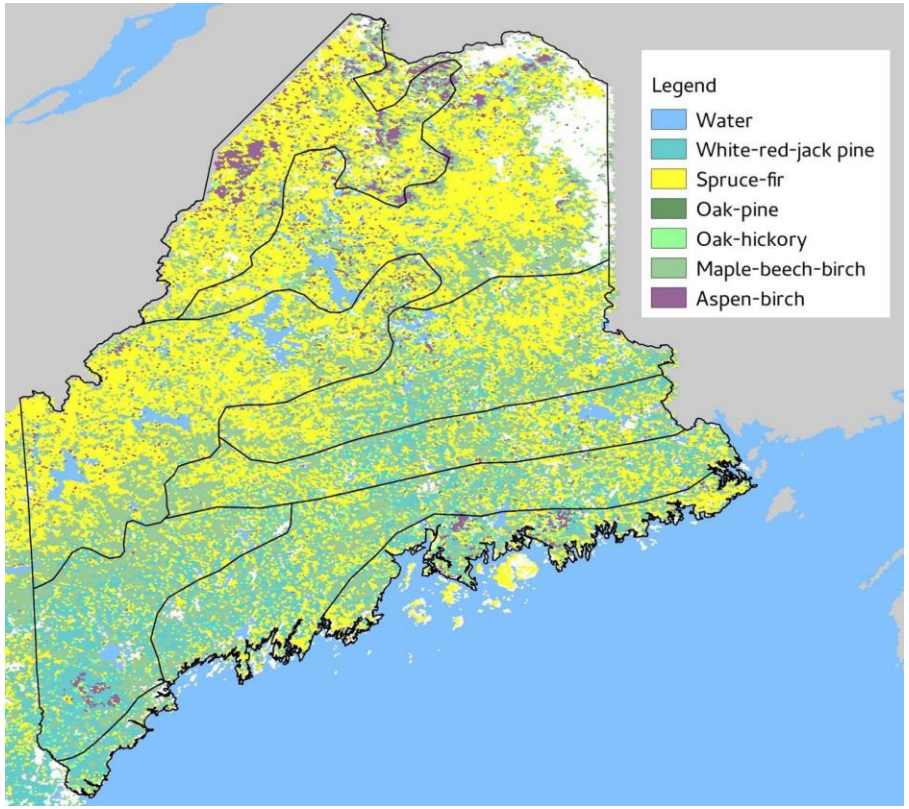
EXECUTIVE ORDER 10, Signed September 23, 2019

- Goal is to achieve state **carbon neutrality by 2045**
- Climate Council is tasked with including recommendations on how to achieve neutrality in its Climate Action Plan
- Carbon neutrality can help grow the clean energy economy in Maine and benefit farmers, foresters, and others whose practices and land sequesters carbon

Governor Mills speaking in New York during the UN Climate Action Summit

Maine's Forest Overview

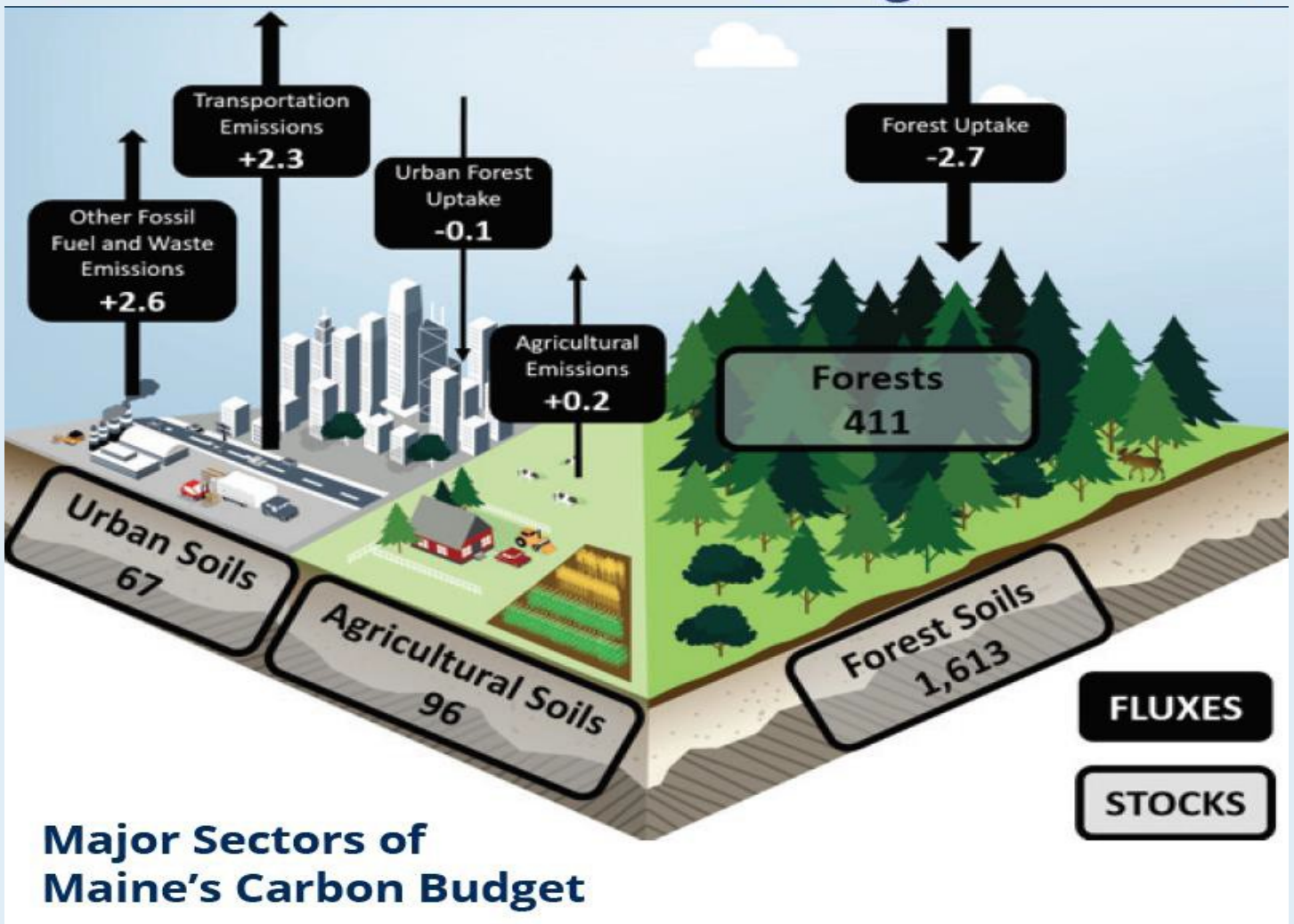
- 83% of state's surface area
- Annually sequesters >60% state's emissions
- Transitional ecosystem
  - Temperate hardwood of south
  - Boreal softwoods of north



Maine's distinct climate zones and primary forest types

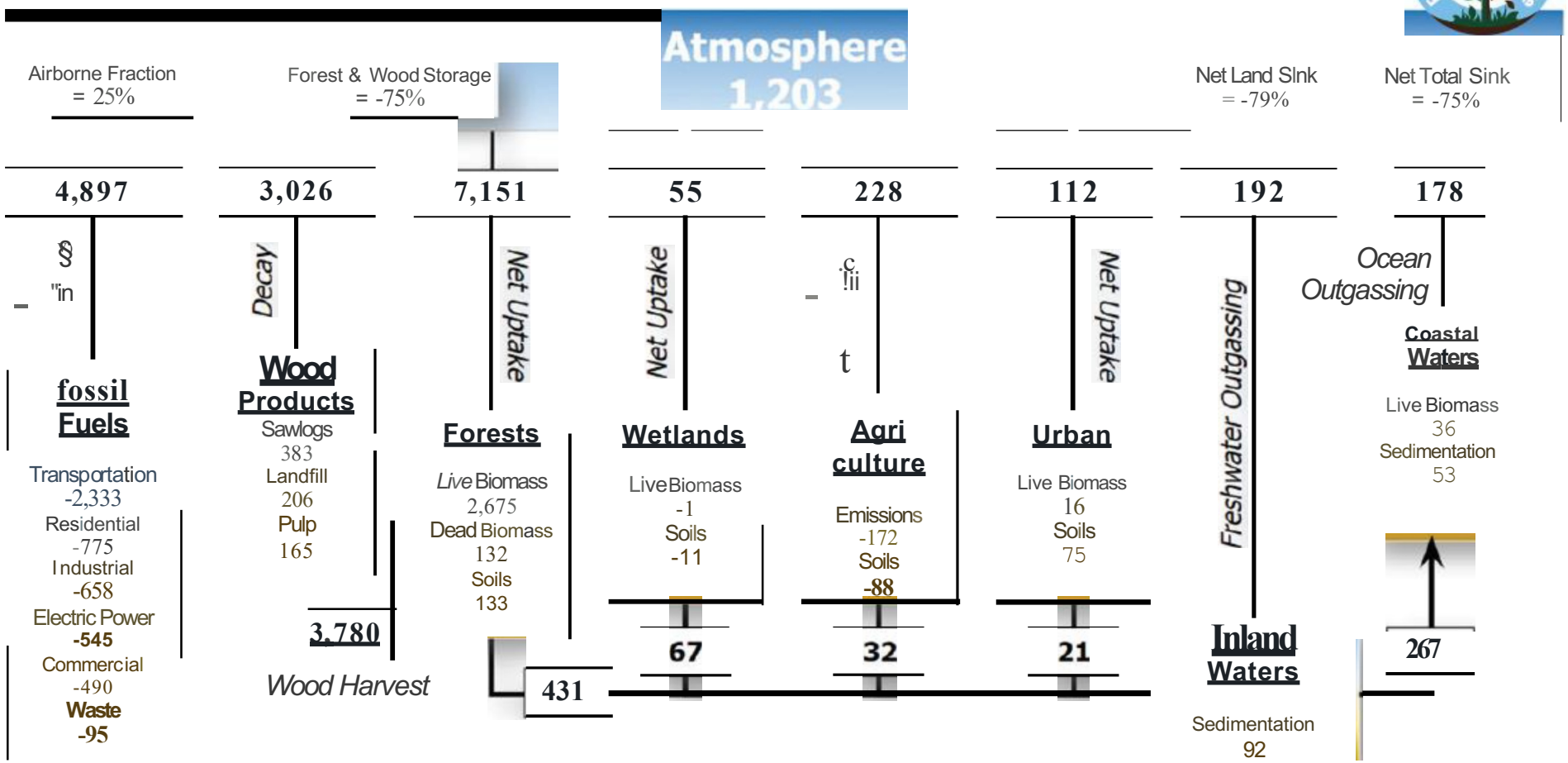
Source: Maine Climate Council Science and Technical Subcommittee – Forest Ecosystems, Forestry, and Biodiversity Subgroup 1/2020

Major Sectors of Maine's Carbon Budget



The simplified C budget of Maine shows estimates of current stocks and annual fluxes in million metric tons of carbon (MMTC, from 2006 to 2016) for the major components. Maine's land-base currently stores more than 2 billion tons C, primarily (~75%) in forest soils. Of the 5.1 MMTC emitted annually by the sources shown, 2.8 MMTC (~55%) is offset by C uptake from forest growth.

Major Components of Maine's Carbon Cycle



The budget illustration depicts the current state of the C cycle in Maine (all estimates are given as annual averages, in thousand metric tons of C per year, for 2007 to 2016). The synthesis of C flows through the various components represents the net effect of Maine's C cycle on the amount of GHGs in the atmosphere-or its co ntr i but ion to the speeding-up or slowing down of climate warming. This budget analysis suggests that -25% of the 4.9 MMTC/ yr emitted on average from fossil fuels in Maine is effectively contributed to the atmosphere (i.e., the "airborne fraction") after accounting for sources and sinks in the state's lands and waters. Using this full budget approach, Maine's net emissions are estimated to be approximately 1.2 MMTC/yr.

Source: Forest Cli m ate Co ange Initiative, Center for Research on Sustainable For ests at the University of Maine.

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Maine Forest Carbon Stock

(MMTC, million metric tons of carbon)

Forest Component	2006 Stock (MMTC)	2016 Stock (MMTC)	Stock Change (MMTC/yr)
Live Biomass	385	412	2.675
Dead Organic Matter	45	47	0.132
Soil Carbon	1,612	1,613	0.133
Total Forest Carbon	2,042	2,071	2.940

Source: Forest Climate Change Initiative, Center for Research on Sustainable Forests at the University of Maine.

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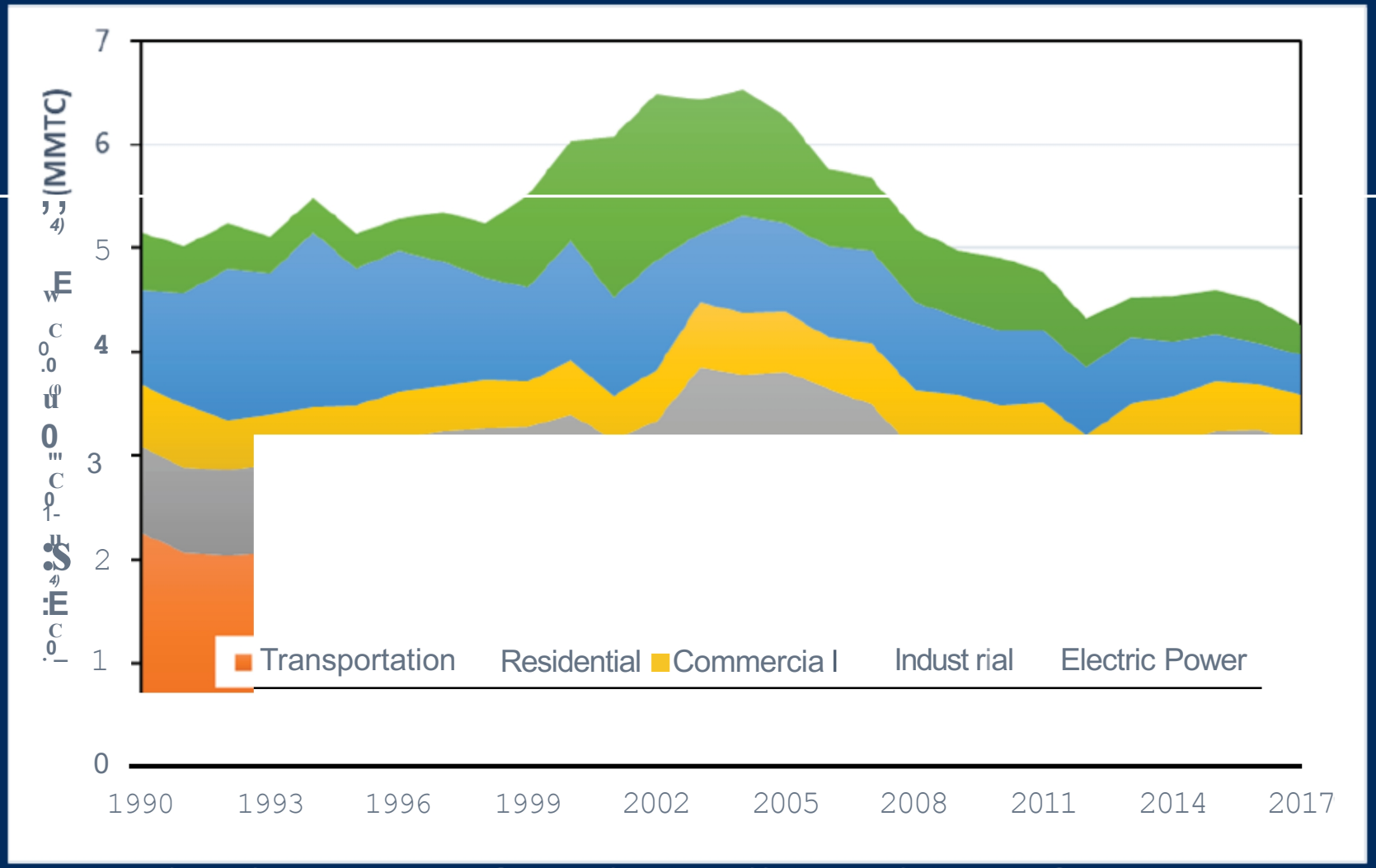
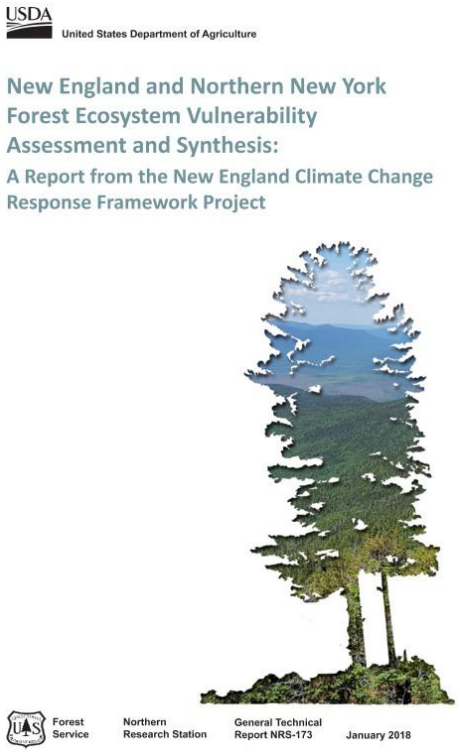
Carbon Emission from Major Sources of Fossil Fuel Combustion in Maine



Source: Forest Climate Change Initiative, Center for Research on Sustainable Forests at the University of Maine. Data source US EPA EIA SEDS (2019).

Key Potential Shifts in Forest Composition



Janowiak et al. (2018)

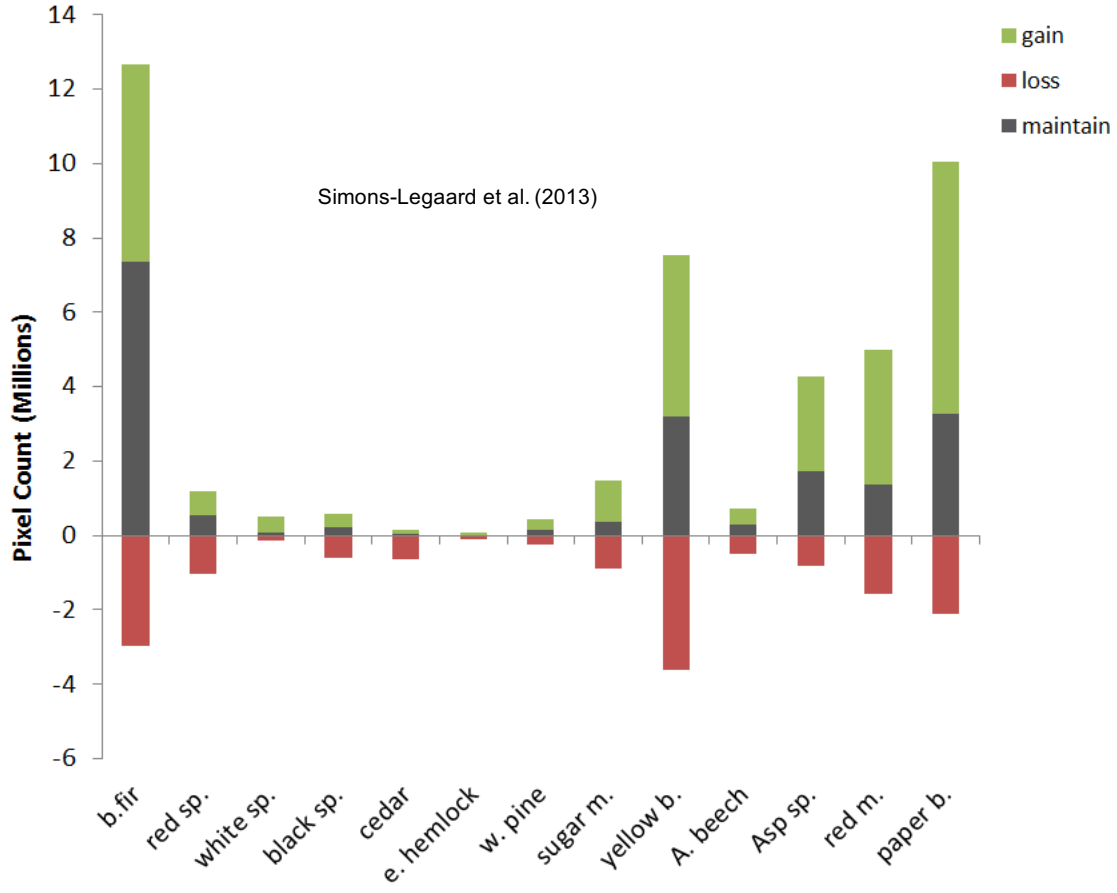
Forest system	Potential impacts	Adaptive capacity	Vulnerability
Central hardwood-pine	Neutral-Positive	Moderate-High	Low
Low-elevation spruce-fir	Neutral-Negative	Moderate	Moderate-High
Lowland and riparian hardwood	Positive and Negative	Moderate-High	Moderate
Lowland mixed conifer	Neutral-Negative	Low-Moderate	Moderate-High
Montane spruce-fir	Neutral-Negative	Moderate	Moderate-High
Northern hardwood	Positive and Negative	Moderate-High	Low-Moderate
Pitch pine-scrub oak	Neutral-Positive	Moderate	Low
Transition hardwood	Positive and Negative	Moderate-High	Low-Moderate

Transition to more hardwood dominated forest types

Source: Maine Climate Council Science and Technical Subcommittee – Forest Ecosystems, Forestry, and Biodiversity Subgroup 1/2020

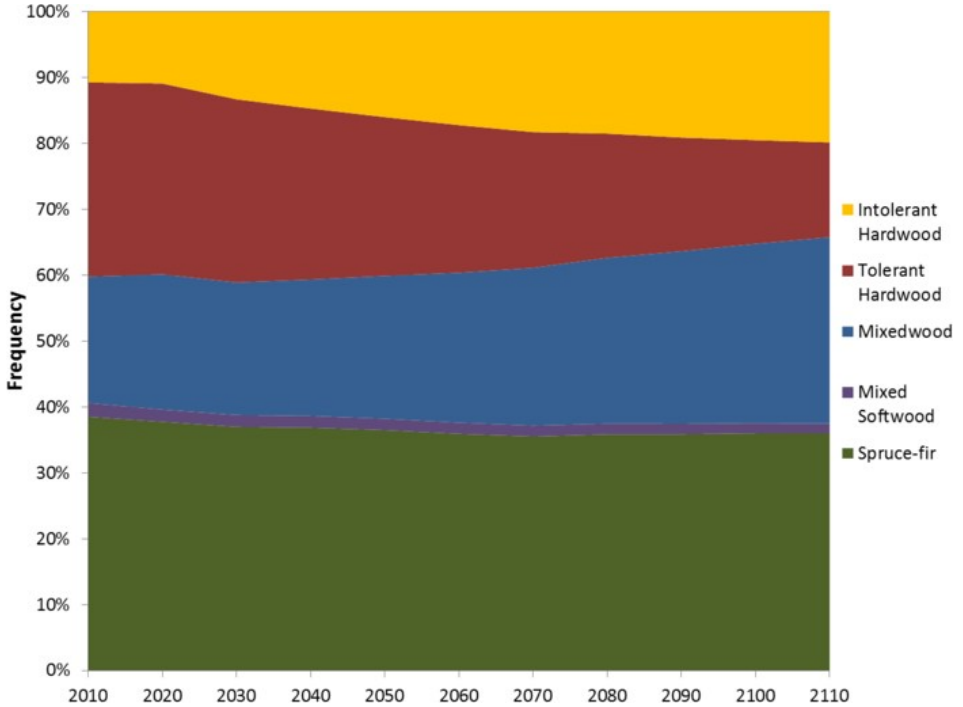
Tree species winners & losers

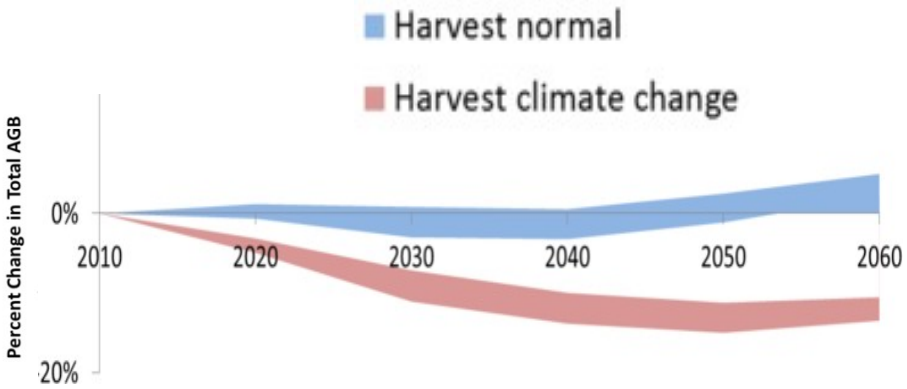
- Slow current proliferation of balsam fir but still remains highly abundant in the future
- Decline of all spruce species
- Birch and maples appear to be the big winners of climate changes



Source: Maine Climate Council Science and Technical Subcommittee – Forest Ecosystems, Forestry, and Biodiversity Subgroup 1/2020

Greater variability of forest productivity





- **Areas may set higher growth due to longer growing seasons, while other areas may decline due to great droughts and occurrence of pests**
  - **Forest management will be a strong influence of future trends**

Source: Maine Climate Council Science and Technical Subcommittee – Forest Ecosystems, Forestry, and Biodiversity Subgroup 1/2020

STATUS: 2004 A CLIMATE ACTION PLAN FOR MAINE

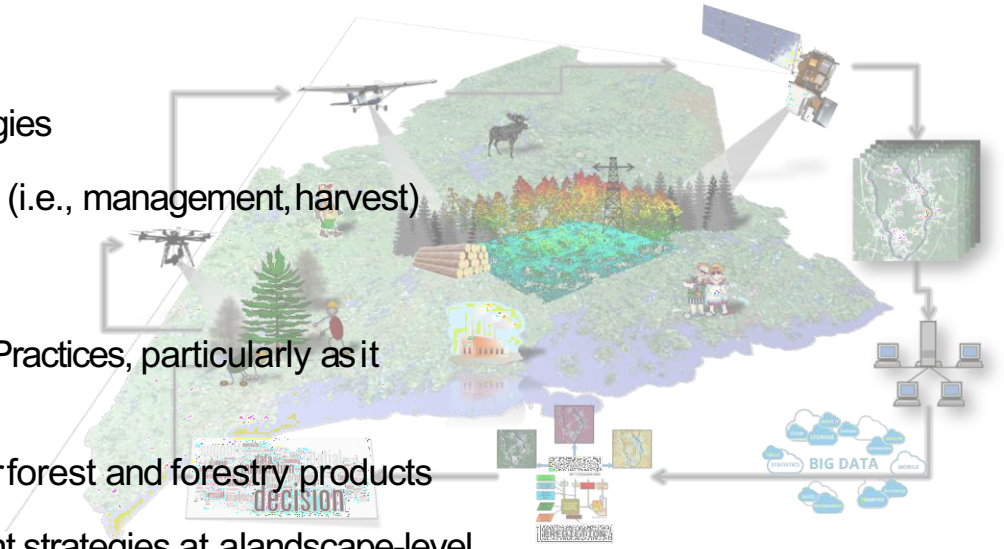
2004 Working Groups	Progress	Recc. #	Brief Description of Measure	Expected $MMtCO_2e$ saved in 2020
Agriculture	Some Evidence of Progress	33	Locally Grown Produce	0.05
		44	Agricultural Land Protection	0.02
		39, 51, 54	Soil Carbon Buildup, including Increase. Organic Farming (#51) and Nutrient Management (#54)	0.03
NWL - Forests	Some Evidence of Progress	14	Forestland Protection	0.48
		16	Early Commercial Thinning	0.28
		28	Active Softwood Increase	0.02
	No Evidence of Progress	10	Increased Stocking with Faster Growing Trees	0.74
		20	Timber Harvest to Capture Anticipated Mortality	0.00
		25	Expanded Use of Wood Products	0.02

References: Maine Climate Hub Mitigation Actions | Maine Climate Action Plan

Priority Information Needs

Forest Impacts

- Improved monitoring of key indicators
- Greater integration of remote sensing technologies
- More studies on human adaptation component (i.e., management, harvest)



Forest Management & Operations

- Develop and revise existing Best Management Practices, particularly as it relates to roads, water-crossing, and culverts
- Complete a full environmental cycle analysis for forest and forestry products
- Evaluate alternative suite of forest management strategies at a landscape-level

Other

- Capacities in-state and corresponding resources and capabilities (e.g. University of Maine Center for Research on Sustainable Forests, Forest Climate Change Initiative, ForEST project)
- Integrated modelling (e.g. degree that soils can be included)
- Atmospheric Chemistry for full accounting of CO_2, CH_4, N_2O and other GHGs (e.g. from Maine's forests, shrublands, wetlands, estuaries, etc.)

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