Carbon Sequestration through Sustainable Forest and Biomass Management

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Introduction

- Clean Power Plan (CPP) and its future...
- EPA's mandate is for a 29% reduction (21 million tons) of CO_2 emitted from existing coal plants in the state of West Virginia from 2012 levels.
- Since 2012, WV has closed six coal-based power plants, reduced 4.4 million tons of CO_2.
- The state would still need additional reductions of 16.6 million tons of CO_2 (4.5 million tC) by 2030.

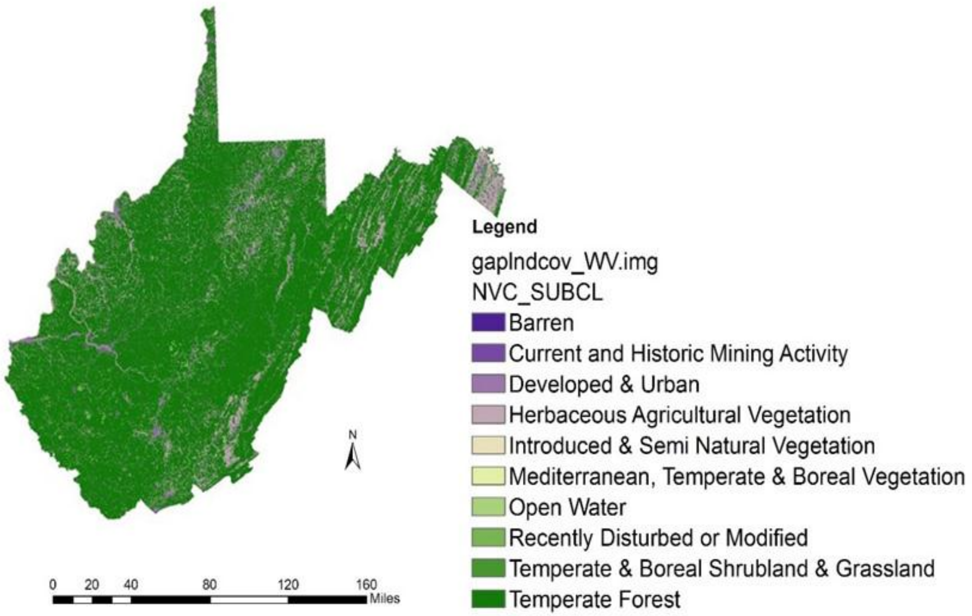
WV DEP. 2016. Feasibility report for a state plan under EPA's Clean Air Act Section 111(d) Rule Regulating Carbon Dioxide Emissions from Existing Fossil Fuel-Fired Electric Generating Units. Charleston, WV.
http://www.dep.wv.gov/pio/Documents/WVDEP%20Feasbility%20Report%204%2020%202016.pdf

Introduction

- Qualified biomass in CPP.
- Adequately demonstrate that the proposed feedstocks appropriately control increases of CO_2 levels.
- Provide sufficient measures to monitor and verify feedstock sources and related sustainability practices.
- Is forest carbon neutral?
- Can sustainably managed natural forests be considered as qualified biomass?

West Virginia Forests

- WV is the third most heavily forested state in term of coverage.
- West Virginia has more than 78% of total land area covered with forest resources.
- The total forest area is 12 million acres (4.8 million hectares).
- 11.79 acres are timber land.



USGS National Gap Analysis Program (GAP) Land Cover Data Portal 2006.

Widmann, R.H., C.R. Dye, G.W. Cook. 2006. Forests of the mountain state. USDA Forest Service Resource Bulletin NRS-17.

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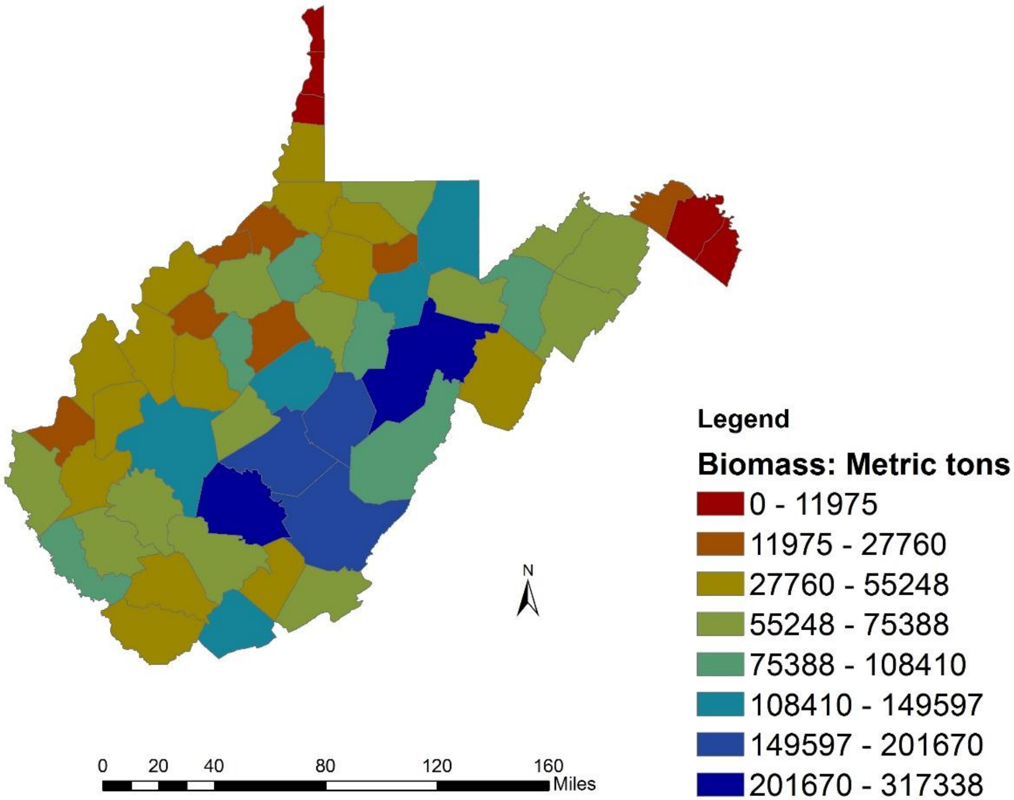
WV Biomass Potential

US DOE billion ton report:

- The total biomass is 4.1 million dry tons at the price of $80/ton.
- Biomass availability would be 3.3, 3.9 and 4.3 million dry tons at the price of $40, $60 and $100/ton.

WV biomass report:

- 0.94-1.1 million dry tons mill residues.
- 1.34-1.39 million dry tons logging residues.



Uses of biomass:
Mill residues - 67% for pellet fuel, 17% for boiler fuel
Logging residue – a small portion being utilized

USDOE Bioenergy: Knowledge Discovery Framework (KDF) Billion Ton Update 2012, Billon Ton Update 2016.
Wang, J., S. Grushecky, J. McNeel. 2007, 2015. Biomass Resources, uses, and opportunities in West Virginia. WVU.

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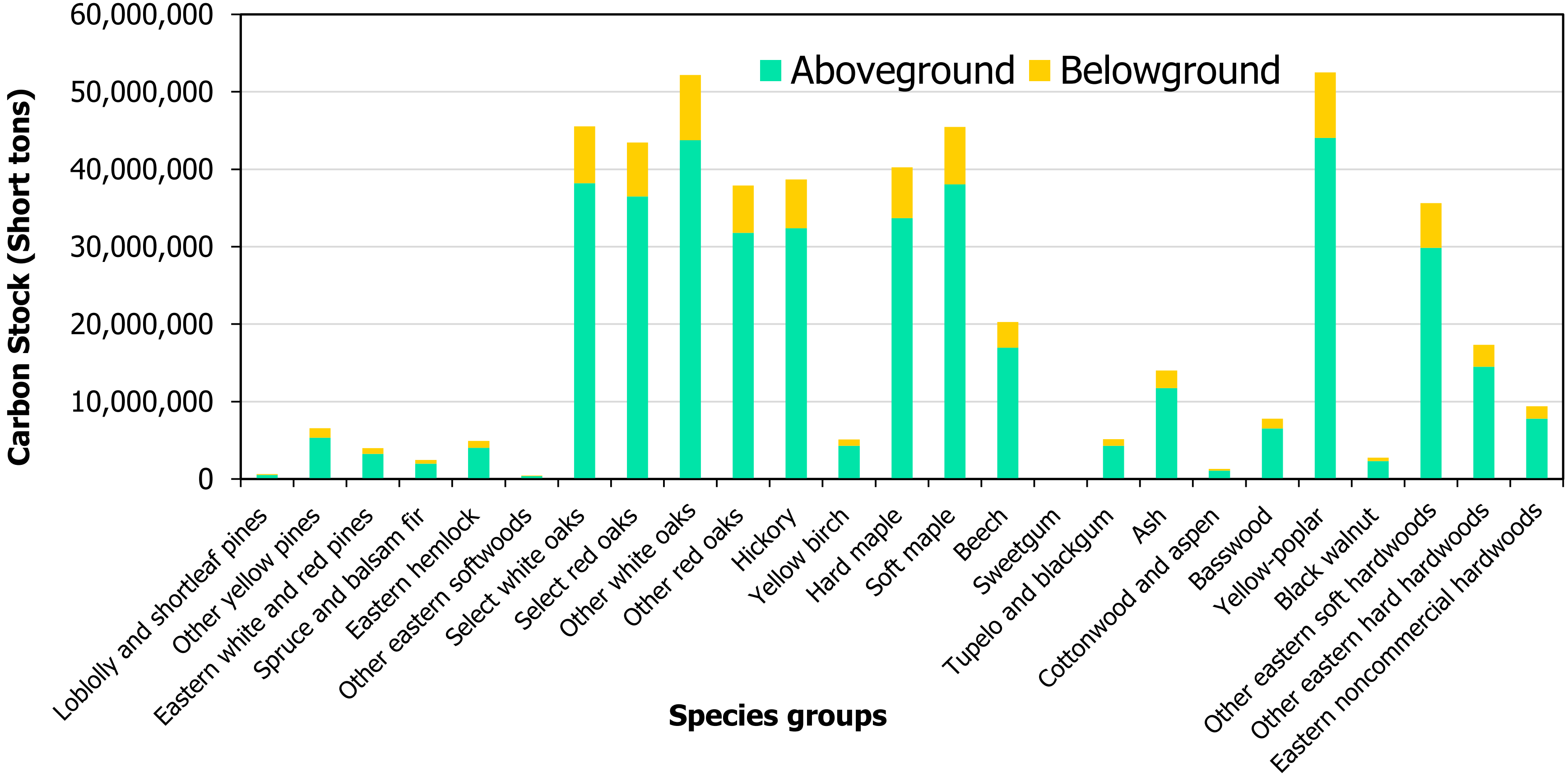
WV Forest Carbon Stock



- The total carbon is 494 million tons in live trees.
- Aboveground is 83.7% and belowground is 16.3%.

USDA Forest Service FIDO standard reports, 2014.

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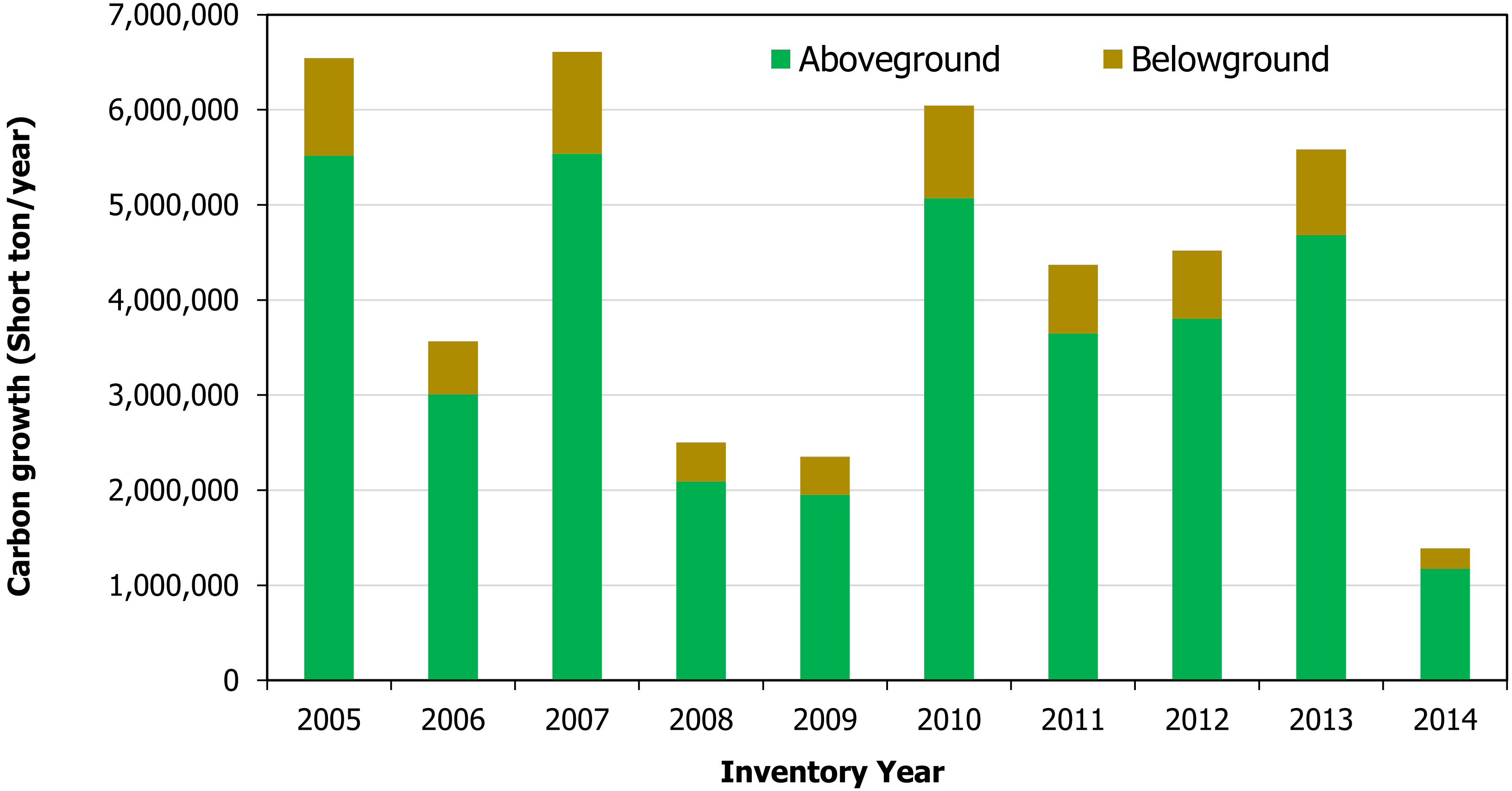
Forest Carbon Growth



The growth of carbon among inventory years is ranging from 1.3 million tons/year to 6.5 million tons/year.

USDA Forest Service FIDO standard reports. 2014

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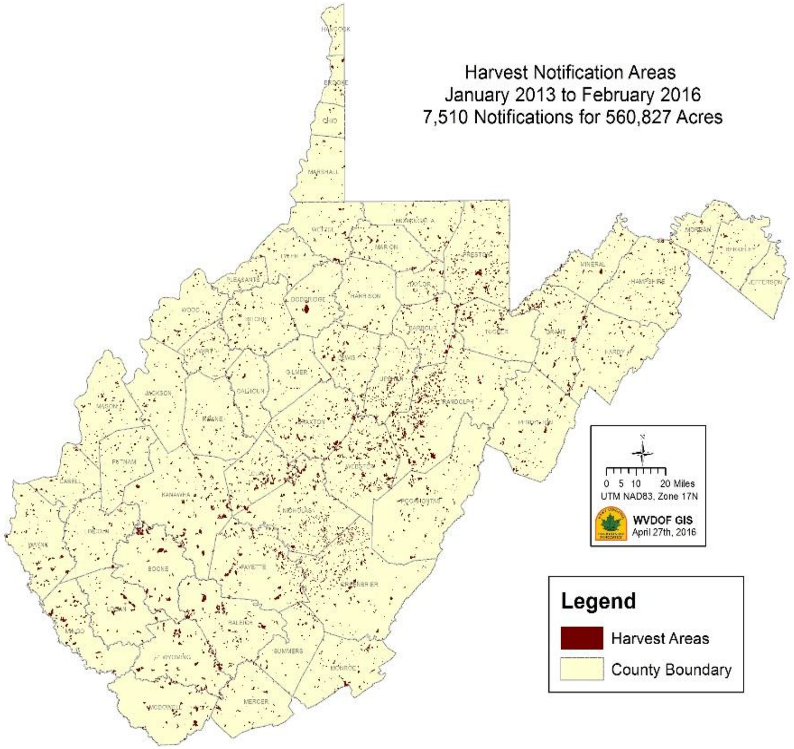
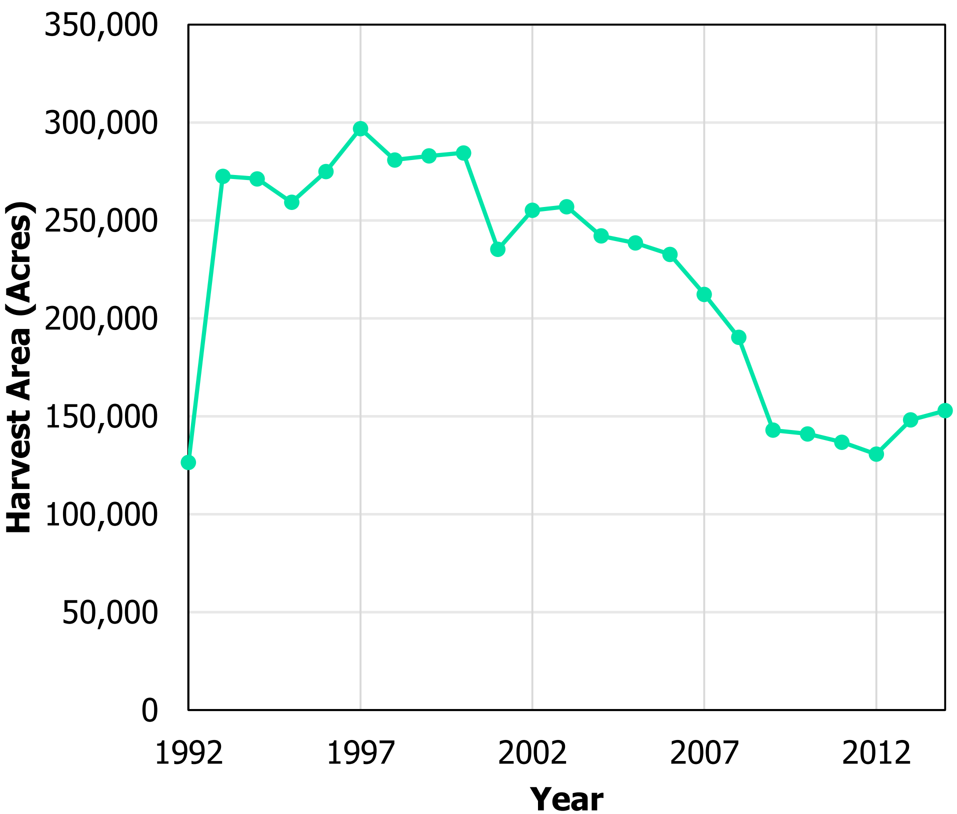
Annual Harvest Areas



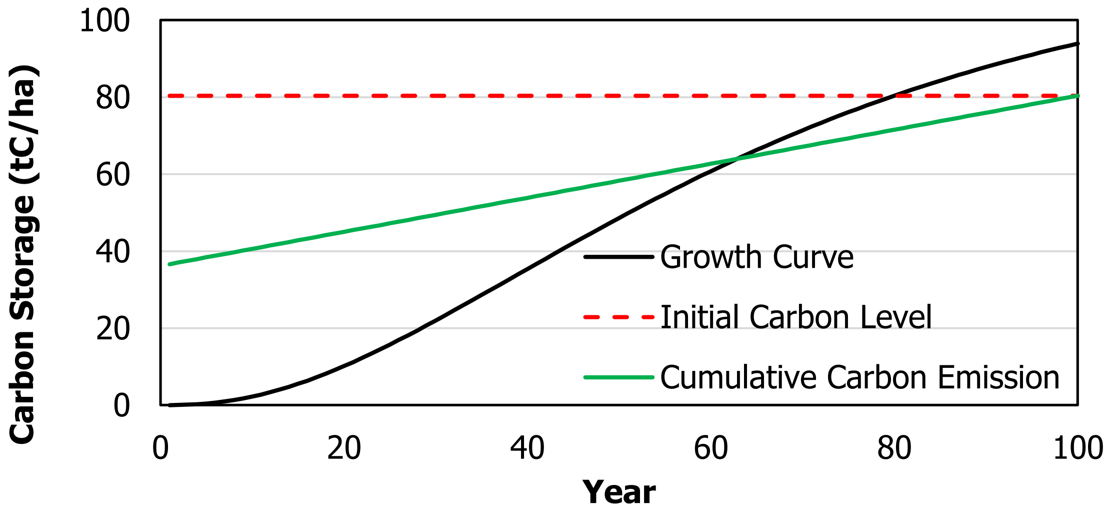


WV DOF harvest notification areas (2013-2015)
The average annual harvest area is 220,221 acres (88,088 Ha).

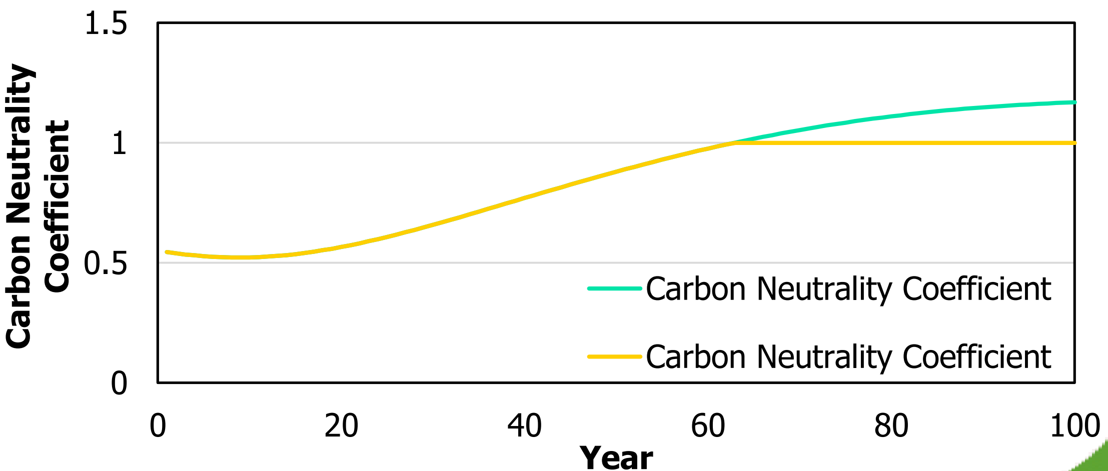
Biogenic Carbon Neutral Concept

A coefficient of carbon neutrality is defined with consideration of carbon harvested, carbon growth, and life cycle emissions:

$$CN_t = \frac{G_t + L_T - tL_T/Y_T}{H_0}$$



t = 0, 1, …, T, is the year after harvest. G_t is the accumulative carbon growth of forest stand.
L_T is the carbon of long lived wood products.
H_0 is the total carbon harvested.
Y_T is the life span of long lived wood product.



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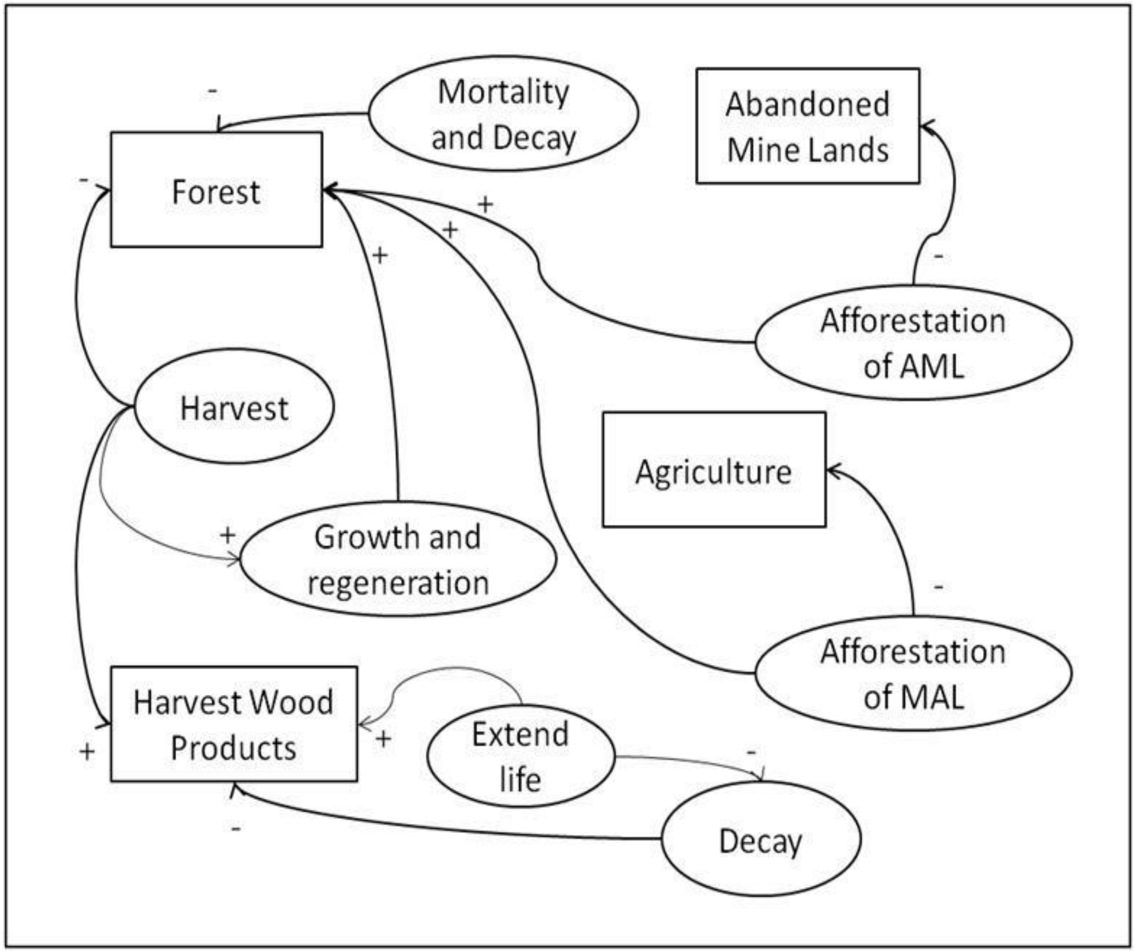
Modeling Carbon Sequestration

- Multiple objectives can be approached by simultaneous optimization of objectives, i.e., to use forests as sustainably as we can.
- These includes…
  - Spatio-temporal optimization under different restrictions
  - Bi-criteria objective function in optimization models
- Bi-criteria objective function with carbon, biomass, and timber products can be formed and optimized.

Carbon Modeling Framework

- C stock in 4 major terrestrial pools
- Related modifying processes
- Using system modeling approach



Sharma, B., J. Wang, and S. Liu. 2010. Development of Spatio-temporal forest harvest planning system for optimizing carbon sequestration. Intelligent Automation and Soft Computing. 16(6):1135-1145.

Optimization Model

$$maximize\ z = a \cdot \sum_{j=1}^{T}\sum_{i=1}^{FB} C_{pv_{ij}} \cdot B_{ij} + b \cdot \sum_{j=1}^{T}\sum_{i=1}^{FB} S_{C_{ij}} \cdot B_{ij} + c \cdot \sum_{j=1}^{T}\sum_{i=1}^{FB} S_{C_{ij+R}} \cdot B_{ij}$$

If objective is to maximize timber and biomass benefits, $\mathrm{a} = 1, \mathrm{b} = 0$ and $\mathrm{c} = 0$;

If objective is to maximize timber and biomass benefits and stand C, $\mathrm{a} = 1, \mathrm{b} = 1$ and $\mathrm{c} = 0$;

If objective is to maximize timber and biomass benefits and stand C after mean recovery period, $\mathrm{a} = 1, \mathrm{b} = 0$ and $= 1$.

$Subject\ to$:

$$\sum_{j=1}^{T-1}\sum_{i=1}^{FB}\left(B_{ij} + B_{i,j+1}\right) \leq 1 \forall MEB$$

$$\sum_{i=1}^{FB} B_i \leq 1\ \forall T$$

$$\sum_{i=1}^{FB}\sum_{j=1}^{T}(1-\nu)H_{ij}B_{ij} \leq \sum_{i=1}^{FB}\sum_{j=1}^{T-1} H_{i,j+1}B_{i,j+1} \leq \sum_{i=1}^{FB}\sum_{j=1}^{T}(1+\nu)H_{ij}B_{ij}$$

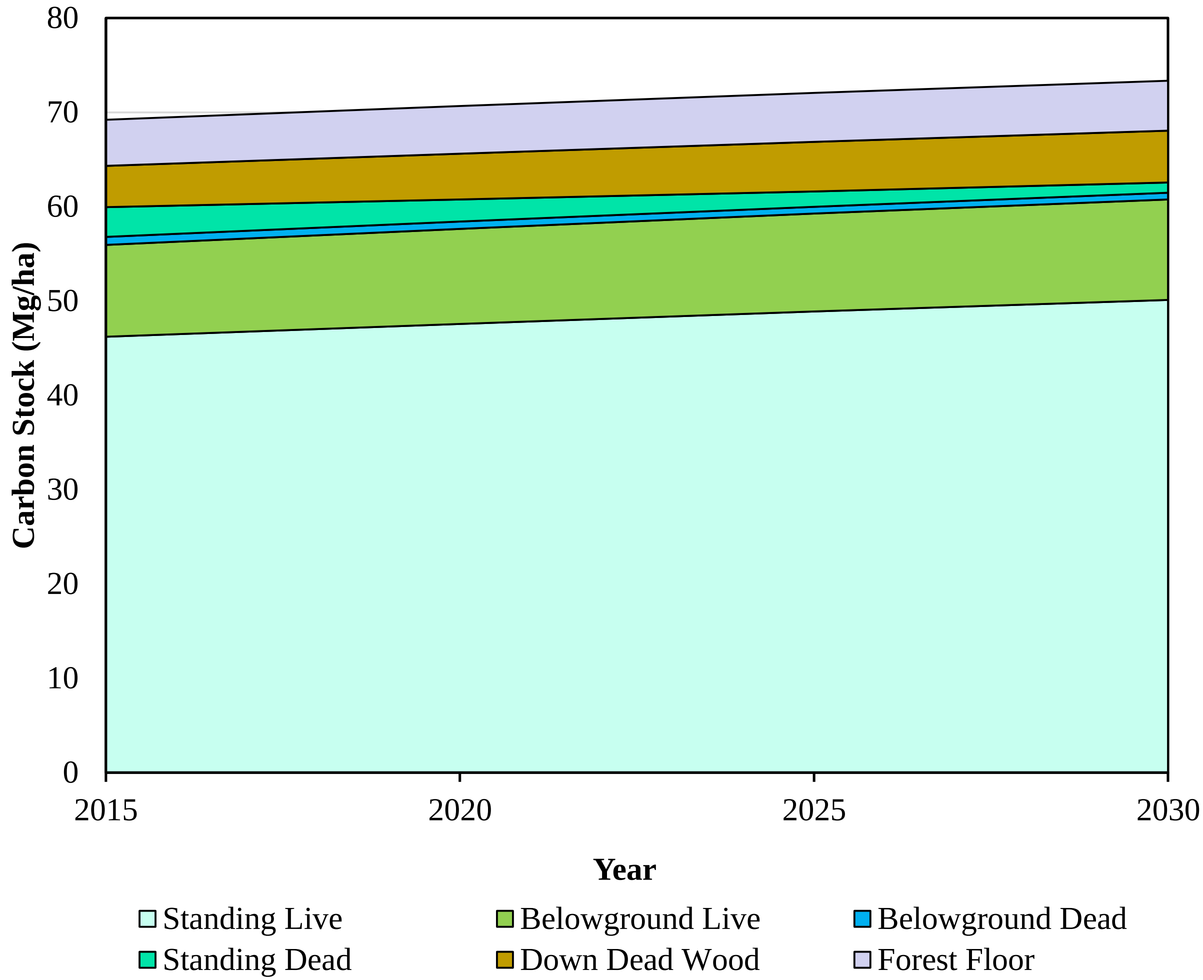
$$B_{ij} \in \{0,1\} \forall FB; \quad C_{pv_{ij}} \notin \{\mathrm{SMZ}\} \forall FB$$

Sharma, B. 2010. Modeling of forest harvest scheduling and terrestrial carbon sequestration. Ph.D. Dissertation. West Virginia University, Morgantown, WV.

Sharma, B. J. Wang, S. Liu. 2011. Modeling of sustainable biomass utilization and carbon emission reduction. Sensor Letters. 9(2011):1175-1179.

Results

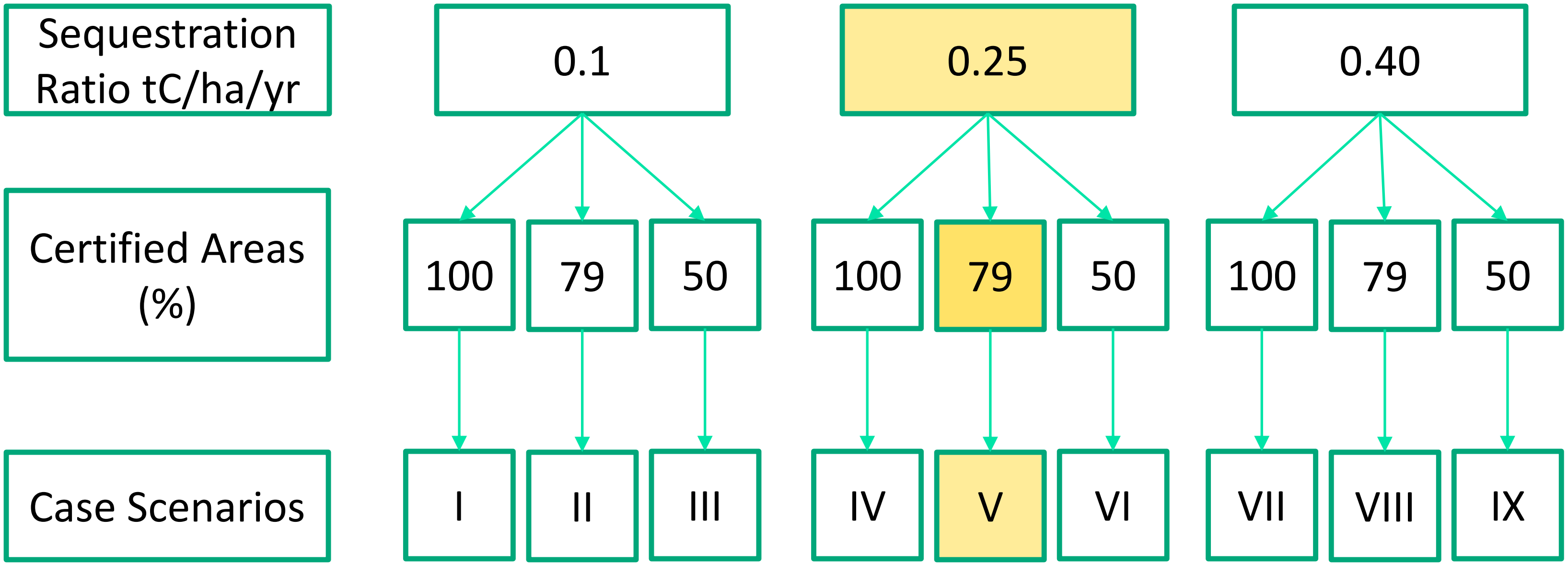
- Net C sequestration in the range of 0.10 - 0.40 tC/ha/year
- Similar proportion of growth and mortality
- Merchantable portion remains half of the total C stock



Wang, J. and J. McNeel. 2009. Carbon sequestration of terrestrial ecosystems in West Virginia: Economic analysis of BTU savings, terrestrial and geological carbon sequestrations. West Virginia University, Morgantown, WV.

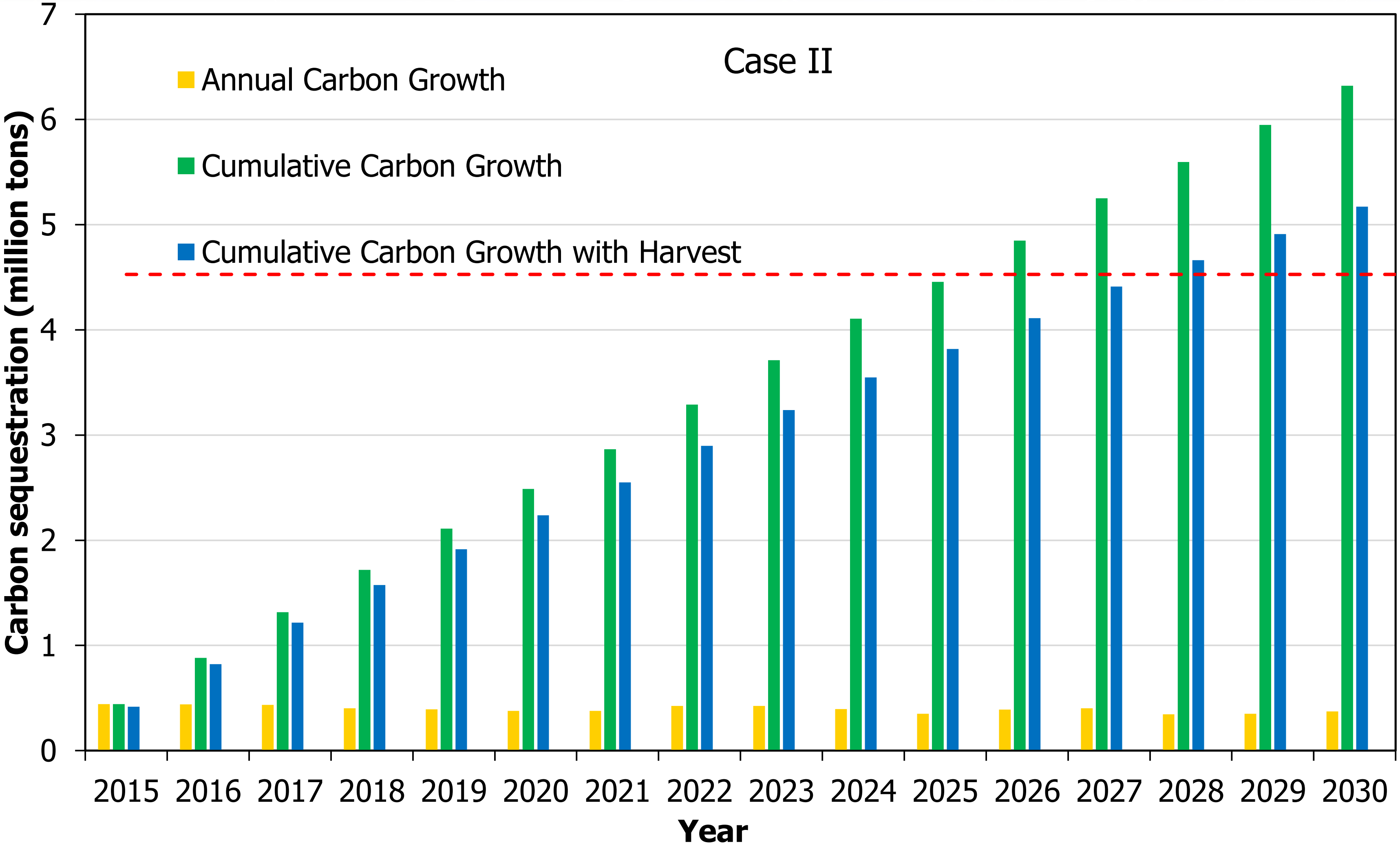
Sharma, B. 2010. Modeling of forest harvest scheduling and terrestrial carbon sequestration. Ph.D. Dissertation. West Virginia University, Morgantown, WV.

Carbon Sequestration Scenarios



Growth to removal ratio: 1.60
Current harvest level
Proportion of utilization remains current
No land use change
Certified by SFI, FSC or ATFS

Forest Carbon Sequestration – Lower Case



To achieve the reduction of 4.5 million tC,
Case I – 2025; Case II – 2028; Case III - 2037

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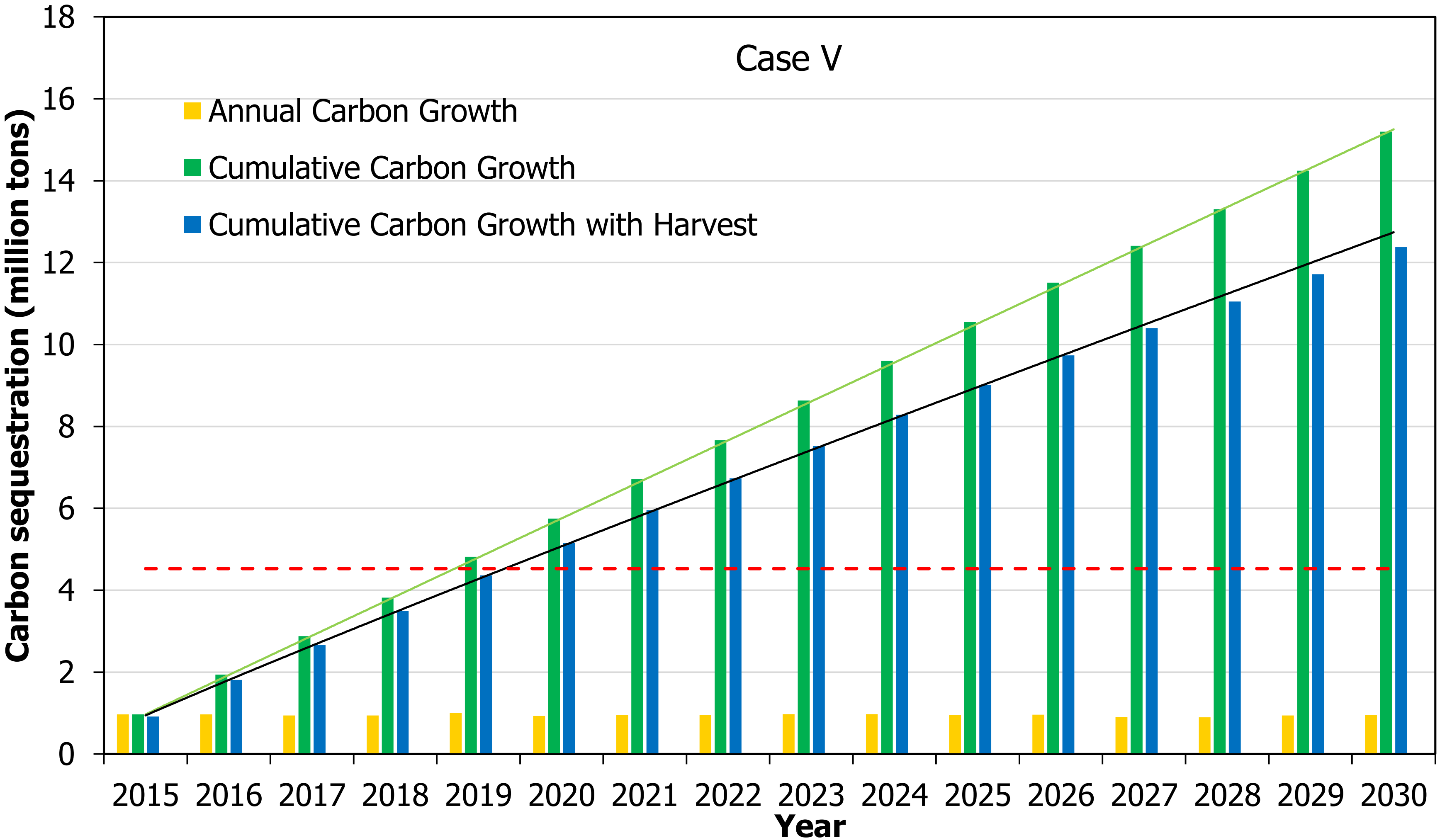
Forest Carbon Sequestration – Base Case



To achieve the reduction of 4.5 million tC,
Case IV – 2019; Case V – 2020; Case IV - 2023

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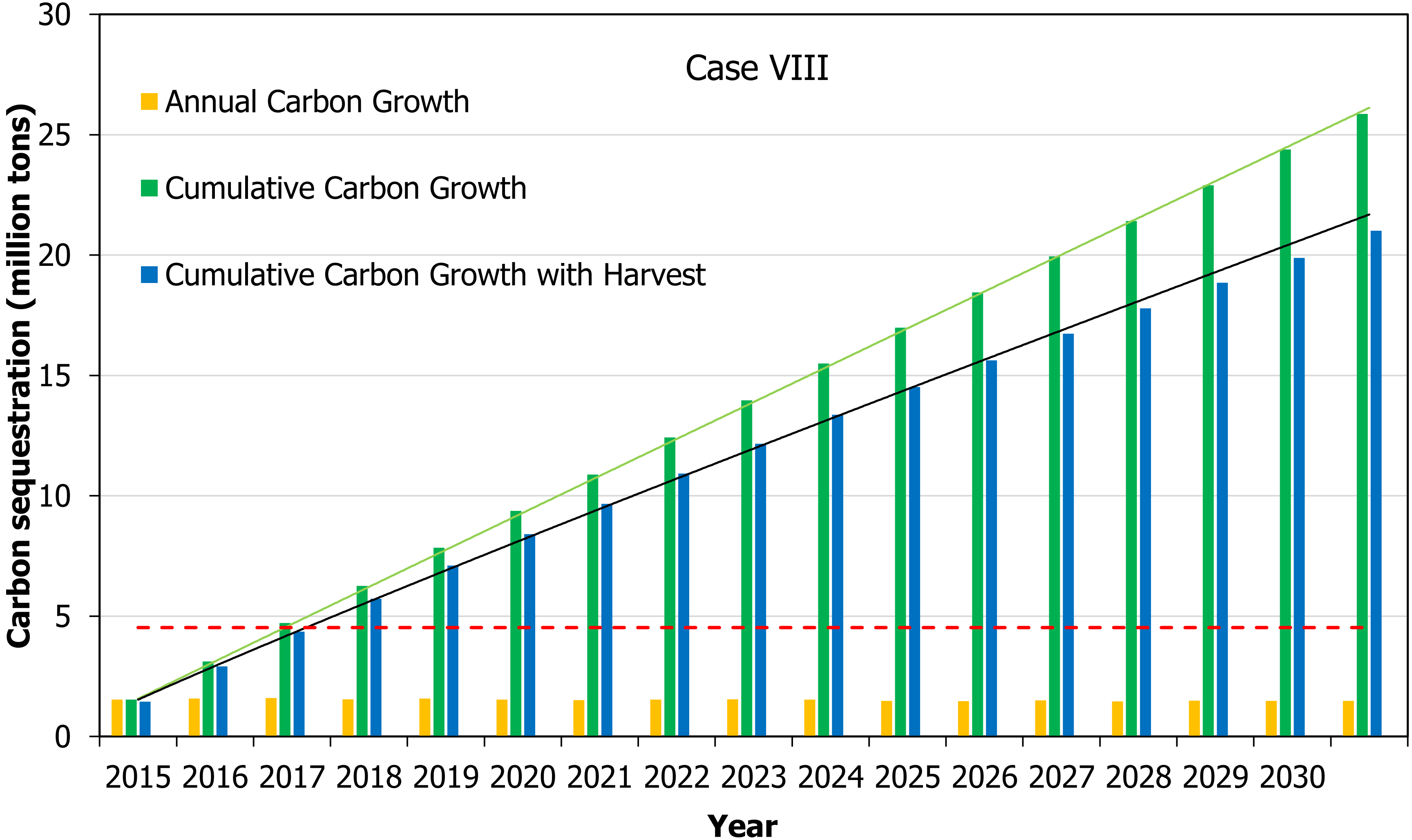
Forest Carbon Sequestration – Higher Case



To achieve the reduction of 4.5 million tC,
Case VII – 2017; Case VIII – 2018; Case IX - 2020

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Summary

- Approximately 1.02-2.72 million tons of C is annually sequestered in terrestrial components of West Virginia.
- Forest growth alone provides over 70% (0.7-2.4 million tons) of the total annual terrestrial sequestration followed by sequestration in harvested wood products.
- It is reasonable to target the CO_2 reduction of 16.6 million tons (23%) by 2030 through sustainable forest management.

Summary

- Many factors affect forest carbon sequestration, and uncertainty exists in the process.
- Change of land use, enhanced growth rate in forests.
- Bioenergy CO_2 Capture and Storage (BCCS).
- Use of biomass as renewable feedstocks for energy and value-added bioproducts.

Sanchez, DL, JH Nelson, J Johnson, A Mileva and DM Kammen. 2015. Biomass enables the transition to a carbon-negative power system across western North America. Nature Climate Change DOI: 10.1038/NCLIMATE2488.

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