Carbon Sequestration through Sustainable Forest and Biomass Management

Jingxin Wang

West Virginia University
Morgantown, WV 26506 USA
Introduction

- Clean Power Plan (CPP) and its future...
- EPA’s mandate is for a 29% reduction (21 million tons) of \( \text{CO}_2 \) 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 \( \text{CO}_2 \).
- The state would still need additional reductions of 16.6 million tons of \( \text{CO}_2 \) (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%20Feasibility%20Report%204%2020%202016.pdf
Introduction

- Qualified biomass in CPP.
- Adequately demonstrate that the proposed feedstocks appropriately control increases of CO₂ 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.


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, Billion Ton Update 2016.
- 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.
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
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.
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

Optimization Model

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

If objective is to maximize timber and biomass benefits, \(a = 1, b = 0\) and \(c = 0\);
If objective is to maximize timber and biomass benefits and stand \(C\), \(a = 1, b = 1\) and \(c = 0\);
If objective is to maximize timber and biomass benefits and stand \(C\) after mean recovery period, \(a = 1, b = 0\) and \(c = 1\).

Subject to:

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

\[
\sum_{i=1}^{FB} B_{i} \leq 1 \forall T
\]

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

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

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

Carbon Sequestration Scenarios

Sequestration Ratio $tC/ha/yr$

- 0.1
- 0.25
- 0.40

Certified Areas (%)

- 100
- 79
- 50

Case Scenarios

- I
- II
- III
- IV
- V
- VI
- VII
- VIII
- IX

Growth to removal ratio: 1.60
Current harvest level
Proportion of utilization remains current
No land use change
Certified by SFI, FSC or ATFS
To achieve the reduction of 4.5 million tC, Case I – 2025; Case II – 2028; Case III - 2037
To achieve the reduction of 4.5 million tC, Case IV – 2019; Case V – 2020; Case IV - 2023
Forest Carbon Sequestration – Higher Case

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

For more information, please contact:
Dr. Jingxin Wang, Professor and Associate Director for Research
Director of Renewable Materials and Bioenergy Research Center
Division of Forestry and Natural Resources
West Virginia University
jxwang@wvu.edu
bioenergy.wvu.edu
Jingxin_wang.forestry.wvu.edu
forestry.wvu.edu
www.newbio.psu.edu
(304) 293 7601