DECISION ANALYSIS MODELS TO EFFECTIVELY INTEGRATE FORESTS INTO CLIMATE CHANGE POLICIES

LAURIE GHARIS
JOSEPH ROISE
FRED CUBBAGE

Outline

- Introduction
- Optimization model

  Theoretical framework, objectives, solution approach
- Application of model for loblolly pine
- Current environmental policies
- Proposed policy
- Application of proposed policy for loblolly pine
- Conclusion

Previous studies

Examples of regional models on forest carbon

- Models on how forest management affects carbon storage
  - Hennigar et al. (2008) – optimization of forest sequestration, product storage, and substitution
  - Eriksson et al. (2007) – simulation of forest carbon sequestration, product storage, and substitution
- Models with economic analyses
  - Nepal et al. (2012)
  - Pohjola and Valsta (2007)
  - Huang and Kronrad (2006)
  - Backeus et al. (2005)

Gap in regional models that optimize management for multiple rotations and multiple objectives, to include economic value, forest sequestration, and product storage and substitution

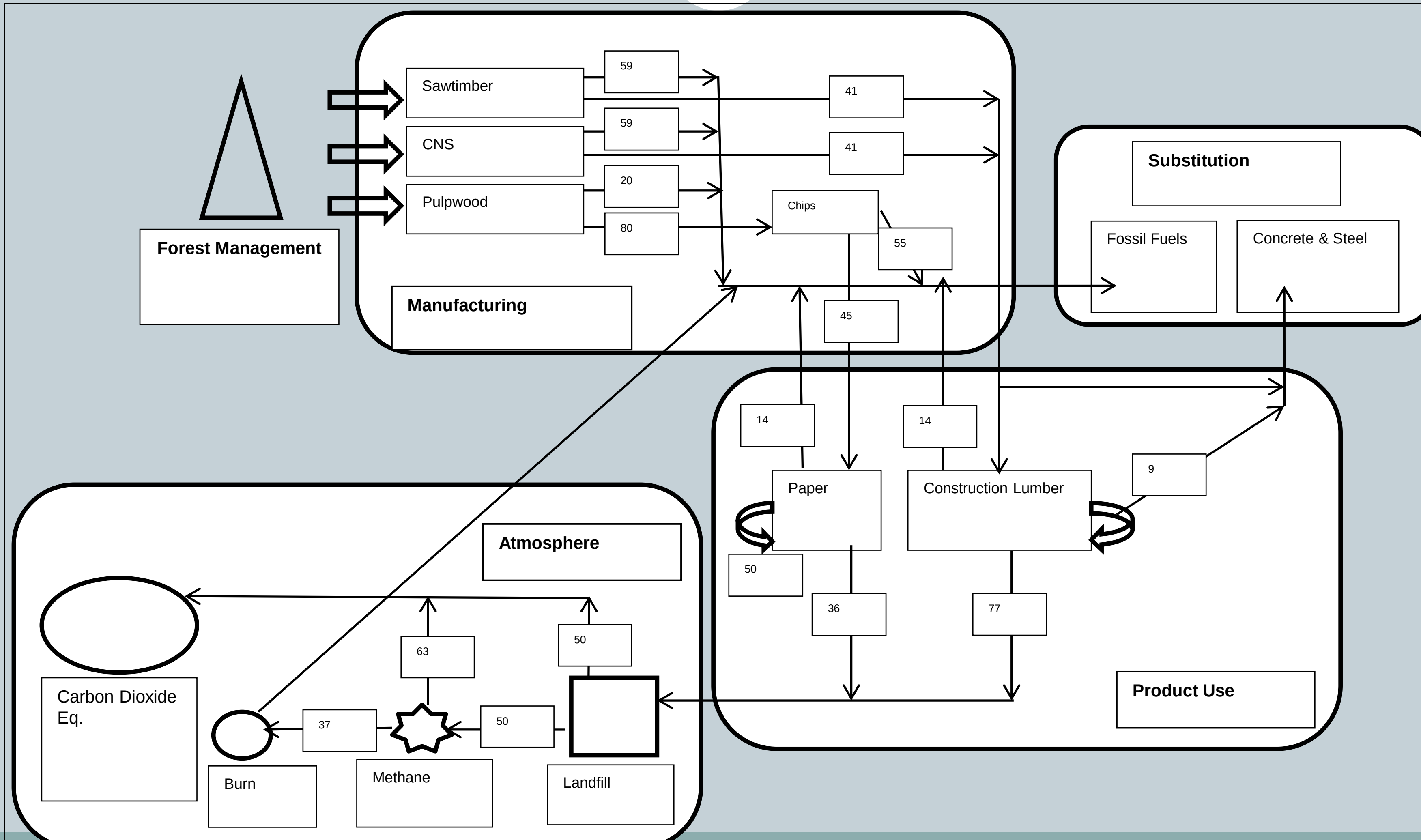
Optimization model

Multiple-objective forest management model to investigate optimal stand level management with three competing objectives:

- Maximizing soil expectation value
- Carbon storage in the forest
- Carbon dioxide emission savings from product storage and substitution

Forest is sustainably managed with no land use changes

Theoretical framework



Decision management variables

Decision management variables for model:

- Planting density, thinning timing and density, and rotation length
- Operational level variables that effect economic value and carbon in the stand

Appropriate growth & yield model

- Integrated growth and yield equations from Hafley and Smith North Carolina State University (NCSU)-Managed Pine Plantation Growth and Yield Simulator-Version 3.2 into optimization model
  - Stand level model utilizes Johnson's S_{BB} distribution to model diameter and height
  - 2,630,003 simulations run over following operable ranges:
    - Site indices 55, 65, 75 feet at base age 25
    - 200 to 1000 trees per acre (TPA) at 10 TPA increments
    - Thinnings between 8-22 years at 1 year increments
    - Residual basal area above 40 square foot per acre at 5 square foot increments
    - Rotation lengths from 20 to 50 years at 1 year increments

Objective-soil expectation value

Maximize SEV

$$S = \left[\left(\sum_{t=0}^{T} (h_t) (1+r)^{-t} - r_c \right) \frac{1}{1-(1+r)^{-T}} \right]$$

$$h_t = f_1(w, x, y, T, v_{k,t})$$

T=rotation length

h_t=stumpage value returns

r=real discount rate (3%)

r_c=regeneration costs (site preparation, planting, seedlings)

h_t is a function of the decision management variables (w-planting density, x-thinning timing and y-intensity, T-rotation length) and of the non-decision variable $v_{k,t}$ price of k, sawtimber, CNS, and pulpwood, at *time t*.

Objective-carbon storage in forest

Maximize carbon storage in the forest

$$C = \sum_{t=0}^{T} (g)$$

$$g = f_2(w, x, y, T)$$

g=forest growth from time zero (bare ground) to *T* (up to 50 years)

g is a function of the decision management variables (*w*-planting density, *x*-thinning timing and *y*-intensity, *T*-rotation length)

Objective-carbon emission savings from product storage and substitution

Maximize carbon dioxide emission savings from product storage and substitution of more fossil fuel intensive products by biofuels and wood construction products

$$\boldsymbol{P} = \sum_{t=0}^{T} (\boldsymbol{w}_p + \boldsymbol{s}_c + \boldsymbol{s}_f)/T$$

$$\boldsymbol{w}_p = f_3(w, x, y, T)$$

$$\boldsymbol{s}_c = f_4(w, x, y, T)$$

$$\boldsymbol{s}_f = f_5(w, x, y, T)$$

$\boldsymbol{w}_p$ =the amount of carbon in wood products using the 100 year method

$\boldsymbol{s}_c$ =the emission savings from substitution of wood construction products

$\boldsymbol{s}_f$ =the emission savings from substitution of fossil fuel products

$\boldsymbol{w}_p$ $\boldsymbol{s}_c$ $\boldsymbol{s}_f$ are all separate functions of the decision management variables (*w*-planting density, *x*-thinning timing and *y*-intensity, *T*-rotation length)

Solution approach

Compromise programming – minimize the gap (Krcmer et al. 2005) between the achieved levels of soil expectation value, carbon storage in the forest, and carbon dioxide emission savings from product storage and substitution and the best values of each objective; each objective is scaled by the inverse of its range (Gershon 1982)

$$L_p(x) = \left\{ \sum_{i=1}^{n} \alpha_i^p \left| \frac{f_i^* - f_i(x)}{f_i^* - f_{i,w}} \right|^p \right\}^{\frac{1}{p}}$$

p value of 100 was employed to simulate a decision maker that has a relatively high risk aversion

Comparison of objectives

Model objective	SEV ($/acre)	Forest carbon (kg of carbon dioxide equivalents/acre)	Product & substitution (kg of carbon dioxide equivalents/acre/year)
Maximize SEV ($/acre)	$1224	199713	1797
Maximize carbon in forest (kg of equivalents/acre)	$923	346043	1824
Maximize carbon in products and product substitution (kg of equivalents/acre/year)	$902	214644	2016

Scenario	Planting density (TPA)	Thin Density (BA)	Thin Year	Rotation (years)
Max SEV	381	65	20	37
Max Ending Forest	575	131	22	50
Max Product and Substitution	575	130	22	28

Comparison of compromise solution

Model objective	SEV ($/acre)	Forest carbon (kg of carbon dioxide equivalents/acre)	Product & substitution (kg of carbon dioxide equivalents/acre/year)
Compromise Solution	$1096	286502	1934
Maximize each objective separately (Best solutions)	$1224	346043	2016
Maximize each objective separately (Worst solutions)	$902	199713	1797
Improvement over worst solution with compromise programming	$194	86789	137

Comparison to established Hafley and Smith Growth and Yield Model: 99% overall, 105% for construction, 92% for pulpwood

Importance of annual carbon

An extra 408 million tonnes of carbon dioxide equivalents are saved over 100 year period if the 12 million planted loblolly pine in the U.S. are planted with multiple rotation, multiple-objective management rather than single rotation, multiple-objective management

Why develop a policy?

- Carbon sequestration is a collective good (Cubbage et al. 2007)
- Carbon dioxide emissions are externalities that the market fails to treat appropriately (Nordhaus 2009)
- People receive benefits from the regulation of ecosystem services (Thompson et al. 2011)

Current environmental policies and markets

- Offsets and mitigation credits stemming from Clean Water Act and Endangered Species Act
  - Mitigation Banking
  - Fort Hood Army Base's Recovery Credit System for the Golden-Cheeked Warbler Habitat
  - Healthy Forests Reserve Program
- Pricing Incentives: cap-and-trade
  - California AB 32 Scoping Plan, Regional Greenhouse Gas Initiative

Current environmental policies and markets, continued

- Market Certification
  - Certified forest landowners manage for multiple objectives and monitor their results (Thompson et al. 2011)
  - Examples: American Tree Farm System, Sustainable Forestry Initiative (SFI), Forest Stewardship Council (FSC) (Moore 2007)
- Payment for Environmental Services
  - Conservation Reserve Program
  - USDA's Longleaf Pine Program
  - Denver Water/U.S. Forest Service's Pairing
  - Willamette Market
- Taxes

Difficulties with current programs

- Conservation Reserve Program
- Healthy Forests Reserve Program
- Forest Certification
- California AB 32 Scoping Plan
- Regional Greenhouse Gas Initiative

Greenhouse gas emissions in U.S.

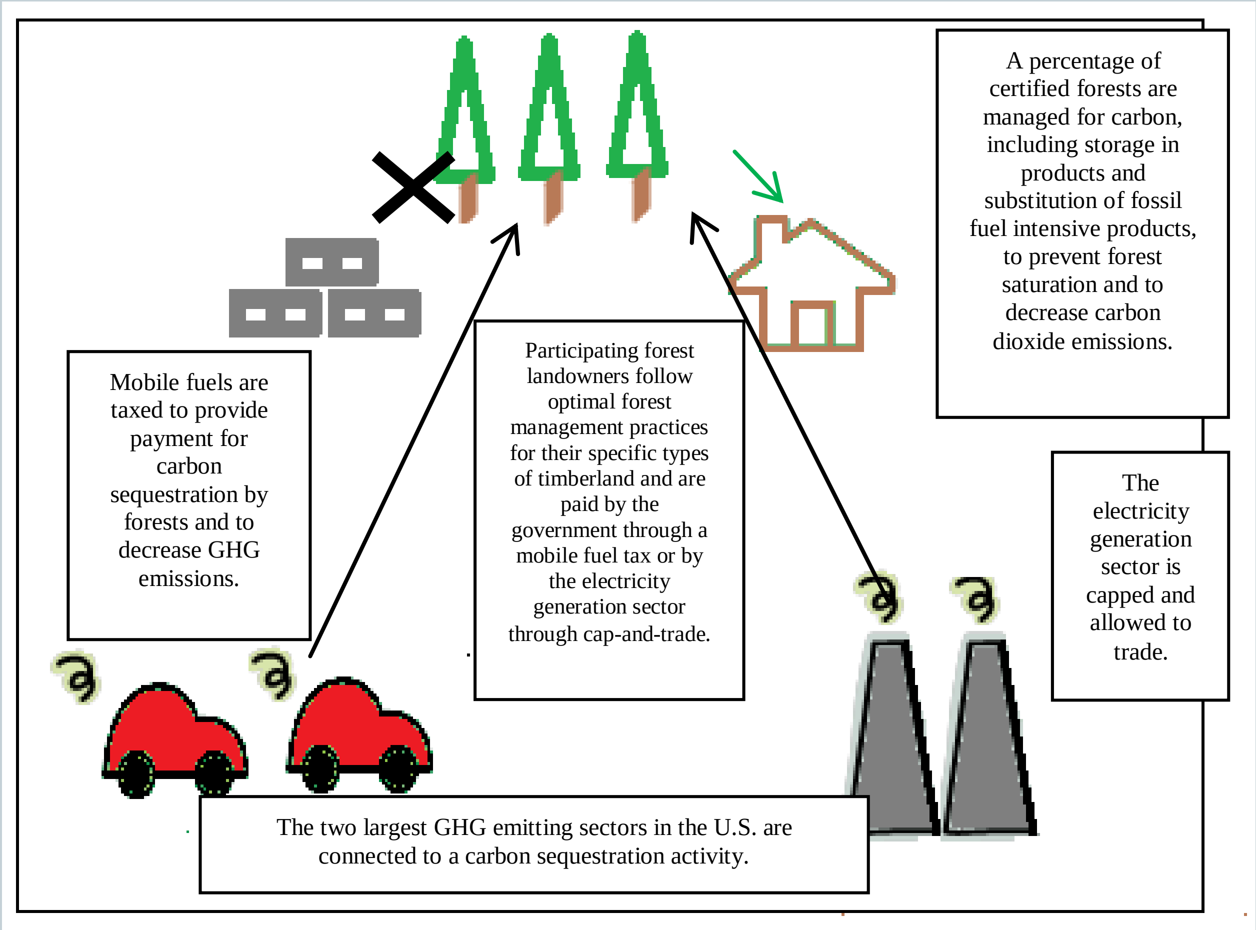
Electricity generation sector (32.4% of U.S. emissions)

- Increased by 18% between 1990-2009 (EPA 2011a)
- ***Cap-and-Trade to bring levels over the next 10 years down to approximately 5% below 1990 levels (UNFCCC 2012)***

Transportation sector (25.9% of U.S. emissions)

- Increased by 16% between 1990-2009 (EPA 2011a)
- ***Tax petroleum products to decrease usage and to provide a revenue source***

Proposed policy model



Valuing carbon

Example for loblolly pine using developed model

- **Business as Usual Baseline** – Managing for soil expectation value ($128/acre more than for multiple-objective model)
- **Additionality** – 5.343 tonnes of carbon dioxide equivalents/acre/rotation

  Cost - $24/tonne of carbon dioxide equivalents
- **Permanence** – 10% mandatory reserve pool
- **Leakage -** offset credits that favor production could prevent reductions in fiber productions and shifts to other parcels of land (Murray and Baker 2011)

Loblolly pine example

- 30 million acres of planted loblolly pine in U.S. (Smith et al. 2009)
- Could prevent an extra 158 million tonnes of carbon dioxide from going into atmosphere over 39 year rotation
- Government would buy the best priced credits (for example 50% of all loblolly credits)
  - To participate, forest landowners would certify their lands
  - Landowners would bid on profit alone in reverse auction
  - Accepted landowners:
    - Would be guaranteed the cost of managing for carbon ($24/tonne of carbon dioxide equivalents) plus bid upon profit
    - Would manage according to optimal management for multiple rotations and multiple objectives of carbon sequestration and economic value

Loblolly pine example-continued

- Optimal management – 476 trees per acre, thin at year 21 leaving a residual basal area of 120 square feet/acre, final felling at year 39
- Administering agency would check at least 10% of offsets for compliance plus projects with 30,000 acres or more

Landowner with 5000 acres enrolled would receive at least $81,240 over 5 years for 3390 tonnes of carbon dioxide equivalents/year

Tax on transportation sector

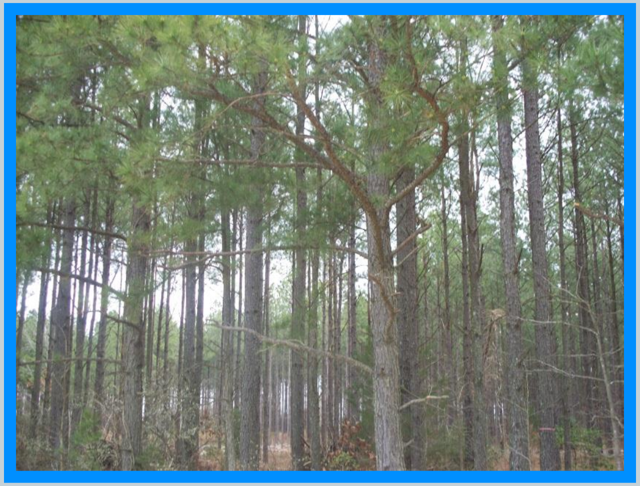
- 181,780.7 million gallons of mobile fuel consumed in 2009 (EPA 2011b)
- Buy half of loblolly pine credits (79 million tonnes of carbon dioxide equivalents)
  - Include administration of program in tax
  - Tax fuels at a little over $0.01/gallon
- Pays for forest sequestration if not bought by electricity generation sector
- Provides revenue source if credits are bought by electricity generation sector

Importance of annual carbon and multiple objectives

- Almost 1 billion people suffered from chronic hunger in 2010
  - Programs that encourage decreased production (Conservation Reserve Program) can lead to shifts in land and increases in food prices
- Climate change policy will require many stakeholders approval and trade-offs from multiple objectives will need to be considered
- A policy such as this of course will face significant political and practical challenges to implementation, but the theory, compromise programming approach, and application described here can foster more discussion about how such an approach could be crafted

Future research

- Focus on categorizing private timberland
- Add more products to the model
- Value carbon for different timberland categories with expected products
- Conduct more sensitivity analyses on non-decision variables



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Questions