Economic efficiency of loblolly pine forests under changing climatic conditions

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BACKGROUND

- U.S. South: forests provide 62% of national timber harvested (Smith et al., 2009), can sequester 23% of regional emissions of greenhouse gases (Han et al., 2007), produce 34% of the regional water yield (Lockaby et al., 2013), and host over 1000 native terrestrial vertebrates with highest species richness.
- These changing climate conditions are expected to significantly affect the production and sustainability of forest-based ecosystem services
- **RESEARCH GOAL**
- The main goal of this study is to economically assess the provision timber production, carbon sequestration, and biodiversity – from loblolly pine forest (*Pinus taeda L.*) plots in the state of Florida under climate change

METHODOLOGY

- A non-parametric approach known as data envelopment analysis (DEA) (Charnes et al., 1978) for the estimation of the economic revenues of ES associated with loblolly pine forests.
- DEA applied to loblolly forest plots in FL.
- Inputs: site index, age of the forest stand, number of tree per plot, average maximum and minimum temperatures, total annual precipitation
- Outputs: timber production, carbon sequestration, species richness
- Input costs: fertilization costs, planting costs
- Output prices: stumpage prices, carbon prices, WTP for species richness.

MODEL SPECIFICATION

- Each j forest plot needs the same x inputs v_{ij} to produce the same y outputs q_{rj}

$$\text{Max } \sum_{r=1}^{y} p_r z_{rk}^{+} + \sum_{i=1}^{x} c_i z_{ik}^{-}$$

subject to

$$\sum_{j=1}^{n} q_{rj}\lambda_j - z_{rk}^{+} = q_{rk}\ (r = 1,2,\dots,y)$$

$$\sum_{j=1}^{n} v_{ij}\lambda_j + z_{ik}^{-} = v_{ik}\ (i = 1,2,\dots,x)$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$z_{rk}^{+} \le \alpha_r q_{rk}\ (r = 1,2,\dots,y)$$

$$z_{ik}^{-} \le \beta_i v_{io}\ (i = 1,2,\dots,x)$$

$$\lambda_j \ge 0, \forall j;\ z_{ik}^{-}, z_{rk}^{+} \text{ free } \forall i, r$$

- Where λ_j represents the shadow price, z_{rk}^{+}, z_{ik}^{-} represent the output shortfalls and input excesses, α_r, β_i represent the degree of discretion to outputs and inputs. p_r is the unit price to the output slacks $\hat{z}_{rk}^{+}$ and c_i is the unit costs to the input slack $\hat{z}_{ik}^{-}$.

APPLICATION TO LOBLOLLY PINE STANDS

Economics

Stumpage prices: $34.2 m^{-3} $27.1 m^{-3} and $17.8 m^{-3} for sawtimber, chip and saw, and pulpwood
Carbon price: $12.5 Mg^{-1} CO_2e
Tree species richness: $6 $plot^{-1}$
Site index: $2.4 m^{-1}
Planting cost: $0.1 $seedling^{-1}$

β for climatic variables and age of trees =0; β=0.5 for site index; $\alpha = \infty$ for outputs

Climatic Scenarios

Three climatic scenarios: Scenario A (Baseline), Scenario B1 (RCP4.5) and Scenario B2 (RCP8.5)

RESULTS

Efficiency analysis	Scenario A	Scenario B_1	Scenario B_2
Number of totally efficient loblolly plots	28	21	21
Profit analysis	\$ $plot^{-1}$ (\$ ha^{-1})		
Average profit (initial conditions)	77.6 (1141)	107.8 (1585)	109.9 (1617)
Average foregone total profit	2.2 (32)	3.1 (46)	3.1 (46)
Optimal average total profit	79.8 (1174)	110.9 (1631)	113 (1661.8)

- Most of the forest plots show a positive profitability regardless of the climatic scenario
- The average profitability of the forest plots increases with moderate (*Scenario B_1*) and high (*Scenario B_2*) changes in climatic conditions.
- Compared to the initial conditions for *Scenario A*, moderate and high changes in climatic conditions increase the profitability of forestlands by 42.8% and 45.6%, respectively.

Total foregone profit π range \$ $plot^{-1}$ (\$ ha^{-1})	Number of plots		
$\pi = 0$	21	21	21
$0 < \pi < 10$ $(0 < \pi < 147.1)$	3	2	2
$10 < \pi < 20$ $(147.1 < \pi < 294.1)$	4	4	4
$\pi > 20$ $(\pi > 294.1)$	0	1	1

- On average, the total foregone profits are \$2.2 $plot^{-1}$ (\$32.4 ha^{-1}) for *Scenario A*, and \$3.1 $plot^{-1}$ (\$45.6 ha^{-1}) for *Scenarios B_1* and *B_2*.
- *In Scenarios A*, *B_1* and *B_2*, 75% (21) of forest plots show zero total foregone profits.