

# Impacts of climate change on economics of forestry and mitigation strategies in the United States South

## BACKGROUND

- In the U.S. South, different studies have postulated an increase in pine forest productivity due to the effect of elevated atmospheric CO<sub>2</sub>.
- Increased temperature and CO<sub>2</sub> would positively impact net photosynthesis of one-year loblolly pine seedlings while increased temperature would have an insignificant impact on net photosynthesis (Wertin et al. 2010).
- Elevated atmospheric temperature and CO<sub>2</sub> would positively impact one-year loblolly pine seedlings growth in its native distribution range (Wertin et al. 2012).
- Decreases in soil moisture due to changes in precipitation regimes may also eliminate the positive effects of increased temperatures and CO<sub>2</sub>.

## OTHER IMPACTS

- Increased insects and pathogen outbreaks; increases in the number and/or severity of wildfires (Hicke et al., 2012; Bachelet et al., 2001).
- Higher frequency of intense hurricanes in the Atlantic basin (Bender et al., 2010; Nordhaus, 2009).

## RESEARCH QUESTION

- What are the impacts of potential changes in :
  - ✓ forest productivity/increased disturbances due to climate change,
  - ✓ silvicultural strategies such as managing tree density and resistant tree species to ameliorate the impact of disturbances on the expected economic returns and optimal rotation age for southern landowners?
- What is the impact of climate change in the supply of C stored in commercial timber?

## MODEL SPECIFICATION

- Reed's economic model (Reed, 1984), LEV and two states of the world:

$$LEV(T) = \frac{\lambda+r}{r[1-e^{-(\lambda+r)T}]} \left\{ \exp^{-rT} U_2 \exp^{-\lambda T} + \int_0^T \lambda \exp^{-rT} U_1 \exp^{-\lambda X} dX \right\}$$

- $U_1 = \bar{g}(X)PV(X) - c$ ; 1<sup>st</sup> state: a catastrophic event arrives at time  $X$  before the optimal rotation age  $T$ . The landowner salvages a proportion of the forest and incurs the regeneration costs associated with the new forest stand.

- $U_2 = PV(T) - c$ ; 2<sup>nd</sup> state: the landowner receives the net returns from harvesting the forest stand at the optimal rotation age  $T$  without being affected by a hurricane, and incurs the replanting costs for a new forest stand.

- $P$ : stumpage price,  $V(X)$ : merchantable volume,  $c$ : regeneration cost;  $\bar{g}(X)$ : mean salvageable portion;  $\lambda$ : probability of a catastrophic risk and  $r$ : discount rate.

## MODEL APPLICATION TO U.S SOUTH'S FORESTS

Table 1. Scenarios and parameters for different species	Original management	Mitigation strategy 1	Mitigation strategy 2
Species	Loblolly pine (LP)	Loblolly pine low density (LP LD)	Slash pine (SP)
Scenarios	A: no changes in growth B: 25% growth increase C: 25% growth decrease		
Tree density tree ha <sup>-1</sup>	1600	1111	1600
$g$	0.2-0.3		0.4-0.5
$\lambda$	0.01-0.03-0.05		
Site index $m$	20		
$P_{sw}$ (sawtimber) \$ m <sup>-3</sup>	28		
$P_{cns}$ (chip-n-saw) \$ m <sup>-3</sup>	18		
$P_{pw}$ (pulpwood) \$ m <sup>-3</sup>	10		
$P_{bm}$ (residues) \$ ton <sup>-1</sup>	2		
$c$ \$ ha <sup>-1</sup>	1025		
$r$	0.04		

## RESULTS

Table 2. LEVs and rotation ages for different forest managements. ( ) represent negative values

			Scenario A		Scenario B		Scenario D		
			Current situation		+25% increased productivity		-25% decreased productivity		
LP	$g$	$\lambda$	LEV	$r$	LEV	$r$	LEV	$r$	
			\$ ha <sup>-1</sup>	yr	\$ ha <sup>-1</sup>	yr	(\$ ha <sup>-1</sup> )	yr	
			0.2	0.01	543.67	23	1396.89	22	(235.95)
			0.03	(874.69)	21	(158.14)	20	(1520.79)	24
			0.05	(2204.42)	20	(1598.08)	19	(2744.60)	22
	0.3	0.01	573.21	23	1434.18	22	(213.12)	25	
		0.03	(804.30)	22	(73.68)	21	(1466.25)	24	
		0.05	(2113.39)	21	(1487.47)	19	(2673.61)	23	
	LP LD	0.4	0.01	692.52	24	1541.33	23	(81.09)	25
0.03			(576.00)	22	149.74	21	(1233.71)	24	
0.05			(1792.03)	21	(1166.49)	20	(2354.82)	23	
0.5	0.01	723.85	24	1580.58	23	(57.96)	25		
	0.03	(502.73)	23	241.72	22	(1178.23)	24		
	0.05	(1694.39)	22	(1044.64)	21	(2280.11)	24		
SP	0.4	0.01	453.91	23	1426.42	22	(426.77)	25	
		0.03	(865.31)	23	(39.95)	21	(1604.47)	25	
		0.05	(2137.09)	22	(1435.70)	21	(2759.25)	24	
0.5	0.01	480.91	23	1461.33	22	(406.76)	25		
	0.03	(796.36)	23	47.74	22	(1553.84)	25		
	0.05	(2045.76)	22	(1317.10)	21	(2690.81)	25		

- Increased forest productivity scenarios lead to higher economic returns. Increased levels of disturbance has the opposite impact.

## RESULTS

- Planting less loblolly pines per ha (LP LD) generates higher LEVs than those for the original LP management under increased forest productivity conditions.
- If landowners decide to plant SP instead of LP, that they will be financially better off as silvicultural efforts aim to increase the amount of undamaged timber.
- Overall, our findings suggest that maintaining forestlands with LP and LP LD is preferred to changing forest composition SP.

## ANALYSIS OF CARBON SEQUESTRATION

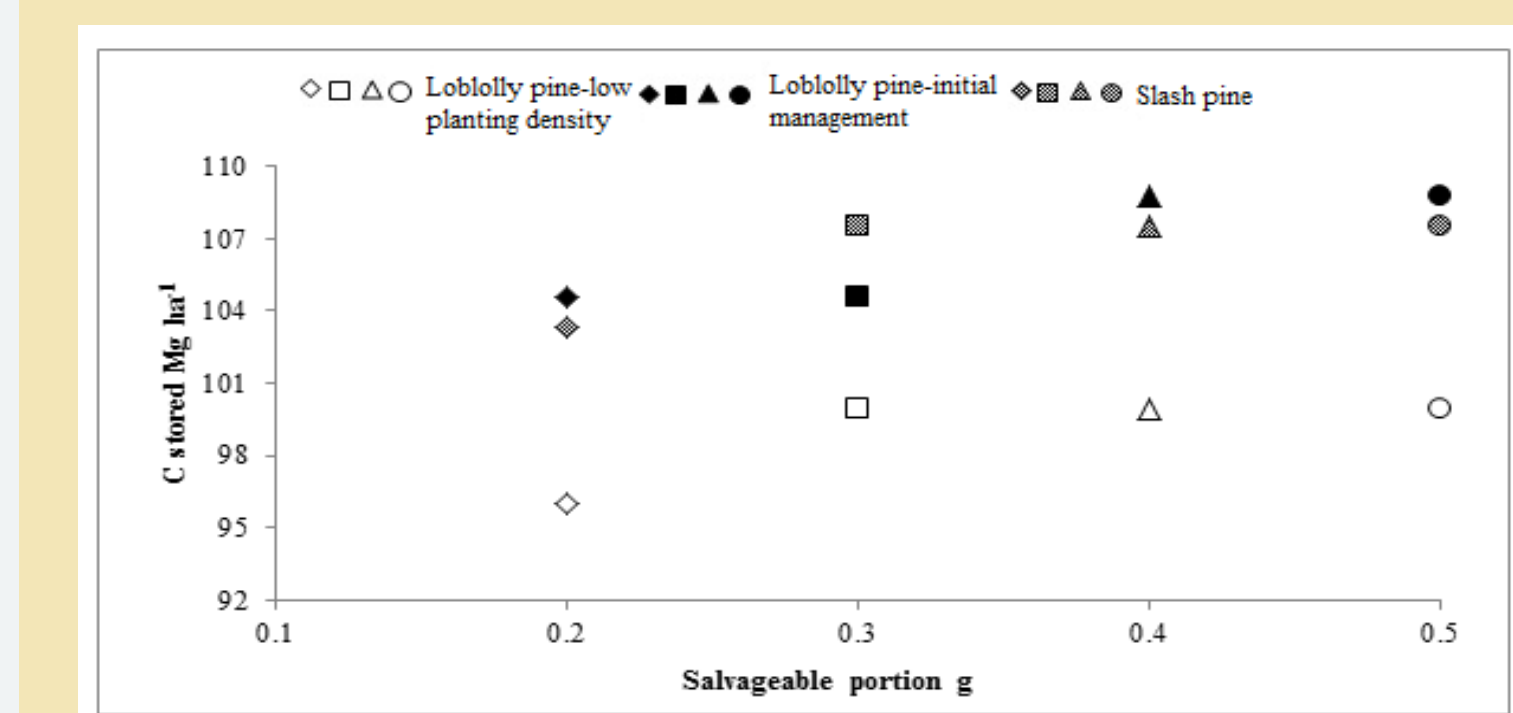


Figure 1. Relationship between stored C and g for different forest managements, scenario B and  $\lambda=0.02$ .

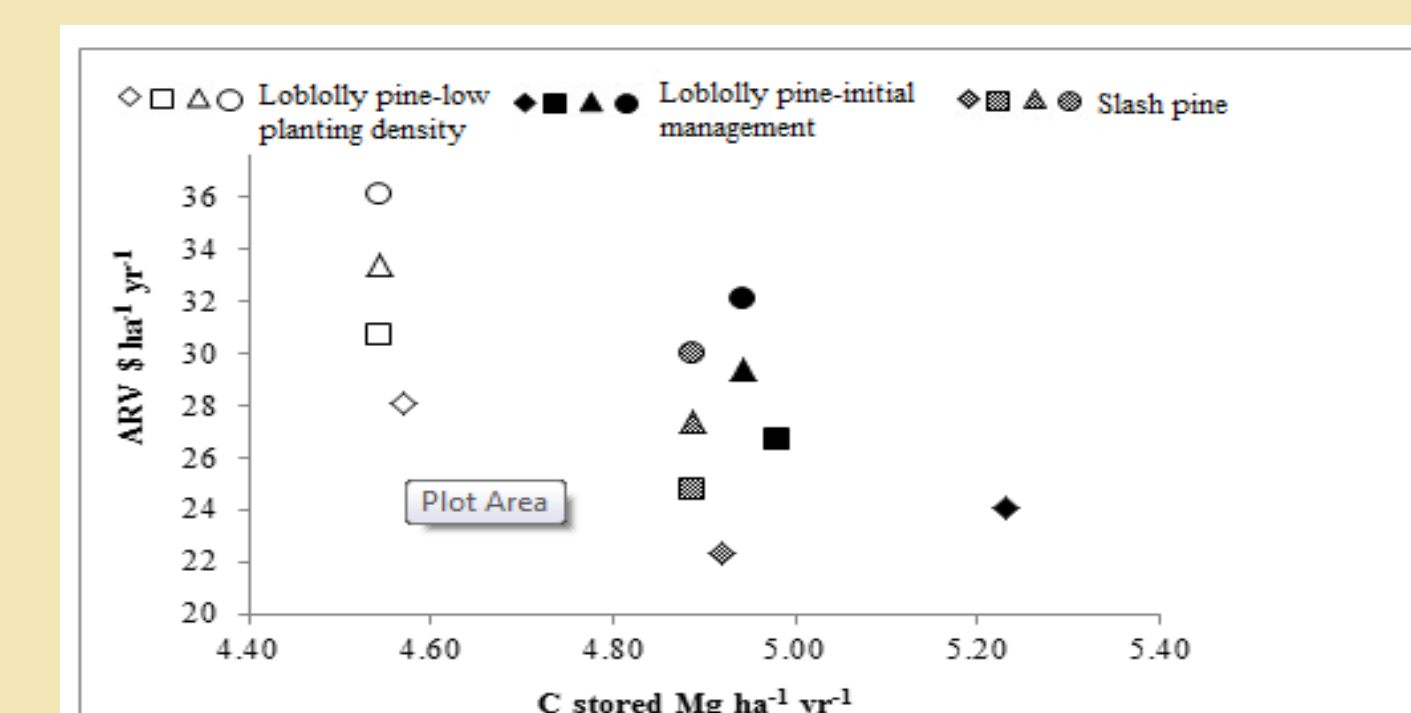


Figure 2. Relationship between ARV and C Stored for  $\lambda=0.02$  and scenario B.

- Planting LP LD results in less sequestered C (100 Mg C ha<sup>-1</sup>) compared to initial LP or SP (107 Mg C ha<sup>-1</sup>) (Fig. 1).
- Similar annual rate of C sequestration for LP LD and SP: from a C sequestration perspective, landowners may not be encouraged to salvage a higher proportion of trees with increased risk of catastrophic (Fig. 1).
- Managing LP LD leads to greater annual rental values (ARV) for the same level of sequestered C outperforming LP and SP by 25% and 35% for a 5 Mg C ha<sup>-1</sup> yr<sup>-1</sup> (Fig. 2).
- SP is more efficient in terms of sequestered C relative to economic rents. For a \$10 increment in land rental values, SP sequesters 5% and 36% more C per dollar compared to initial LP and LP LD (Fig. 2).

## CONCLUSIONS

- Increased (decreased) forest productivity scenarios lead to higher (lower) economic returns for forest landowners.
- Increased levels of disturbance risk due to climate change worsen the profitability of forestry regardless of the forest productivity scenario.
- The selection of adequate forest species and management thus become crucial to capture the benefits and mitigate the negative effects due to climate change.

## References

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