A generalized economic model for carbon sequestration: Implications for sustainability of forestlands in the U.S. South

Andres Susaeta[1], Douglas Carter[1], Sun Joseph Chang[2]

[1]School of Forest Resources and Conservation, University of Florida-IFAS, Gainesville, FL, USA

[2]School of Renewable Natural Resources, Louisiana State University, Baton Rouge, LA

BACKGROUND

- Anthropogenic emissions of greenhouse gases (GHG), particularly CO_2, are considered the main drivers of climate change
- In the U.S. South, carbon stored in forests was estimated at 12400 Tg in 2010 (Huggett et al. 2011)
- Forests in the south-central and southeast regions have the potential of sequestering 23% of the regional total GHG emissions
- Forests in the southeastern coastal plain can sequester around 1 Mg ha^{-1} yr^{-1}.

RESEARCH GAP

- Models such as those based on a Faustmann-Hartman framework (1976) have assumed that certain parameters such as prices of carbon, remain constant over successive rotation ad infinitum
- However, these parameters are likely to fluctuate after each or several rotations.

MODEL ASSUMPTION

- Annually, a forest landowner will receive a subsidy for each m^3 sequestered in the timber biomass
- Likewise, a forest landowner will pay a tax per m^3 harvested.
- Let's define for t_i year old trees at the ith timber crop:

$P_i(t_i)$: price of stumpage; $Q_i(t_i)$: the merchantable volume; C_i: the regeneration cost P_c: price of carbon sequestered; α_i: amount of Mg of carbon per m^3 of wood factor; β_i: proportion of wood sequesters carbon in long-lived product and landfills; r_i: discount rate.

MODEL SPECIFICATION

- The land expectation value at the beginning of the first timber crop LEV_1 is:

$$\mathbf{LEV_1} = \{-C_1 e^{r_1 t_1} + P_1(t_1)Q_1(t_1) + e^{r_1 t_1}\int_0^{t_1} P_c\alpha_1 \frac{dQ_1(s_1)}{ds_1} e^{-r_1 s_1}\, ds_1 - E_1(t_1)\}e^{-r_1 t_1} + e^{-r_1 t_1} LEV_2 \quad (1)$$

$E_1(t_1) = P_c\alpha_1 Q_1(t_1)[1-\beta_1]$ thus Eq. (1):

- Assuming k different crops and letting $V_k(t_k)$=stumpage value, where $V_k(t_k) = [P_k(t_k)Q_k(t_k)]$, we obtain the following first order condition with respect to t_k:

$$\frac{\partial V_k(t_k)}{\partial t_k} + P_c\alpha_k \frac{\partial Q_k(t_k)}{\partial t_k} - \frac{\partial E_k(t_k)}{\partial t_k} = r_k[V_k(t_k) - E_k(t_k)] + r_k LEV_{k+1} \quad (2)$$

- The LHS of Eq. (2) represents the net marginal revenues of timber and carbon benefits by waiting extra one year. The RHS of) represents the marginal cost of waiting one extra year.

IMPLICATIONS ON OPTIMAL HARVEST AGE

- Rule of harvest: if LHS> RHS ⇒wait for one more time period, if LHS≤ RHS ⇒harvest
- Harvest is postponed if $LEV_{k+1} < \varphi(t_k) = [\frac{\partial V_k(t_k)}{\partial t_k} + P_c\alpha_k\frac{\partial Q_k(t_k)}{\partial t_k} - \frac{\partial E_k(t_k)}{\partial t_k} - r_k[V_k(t_k) - E_k(t_k)]]/r_k$
- A higher current price of carbon P_c implies a reduction of the RHS of Eq. (2). It would also increase the LHS of Eq. (3). Thus, $\frac{\partial V_k(t_k)}{\partial t_k}$ has to be reduced to restore the equality, lengthening the current harvest age
- On the other hand, a higher P_c for future timber crops would only increase future land values LEV_{k+1}. $\frac{\partial V_k(t_k)}{\partial t_k}$ would have to be increased to hold the relationship, thus decreasing the harvest age.

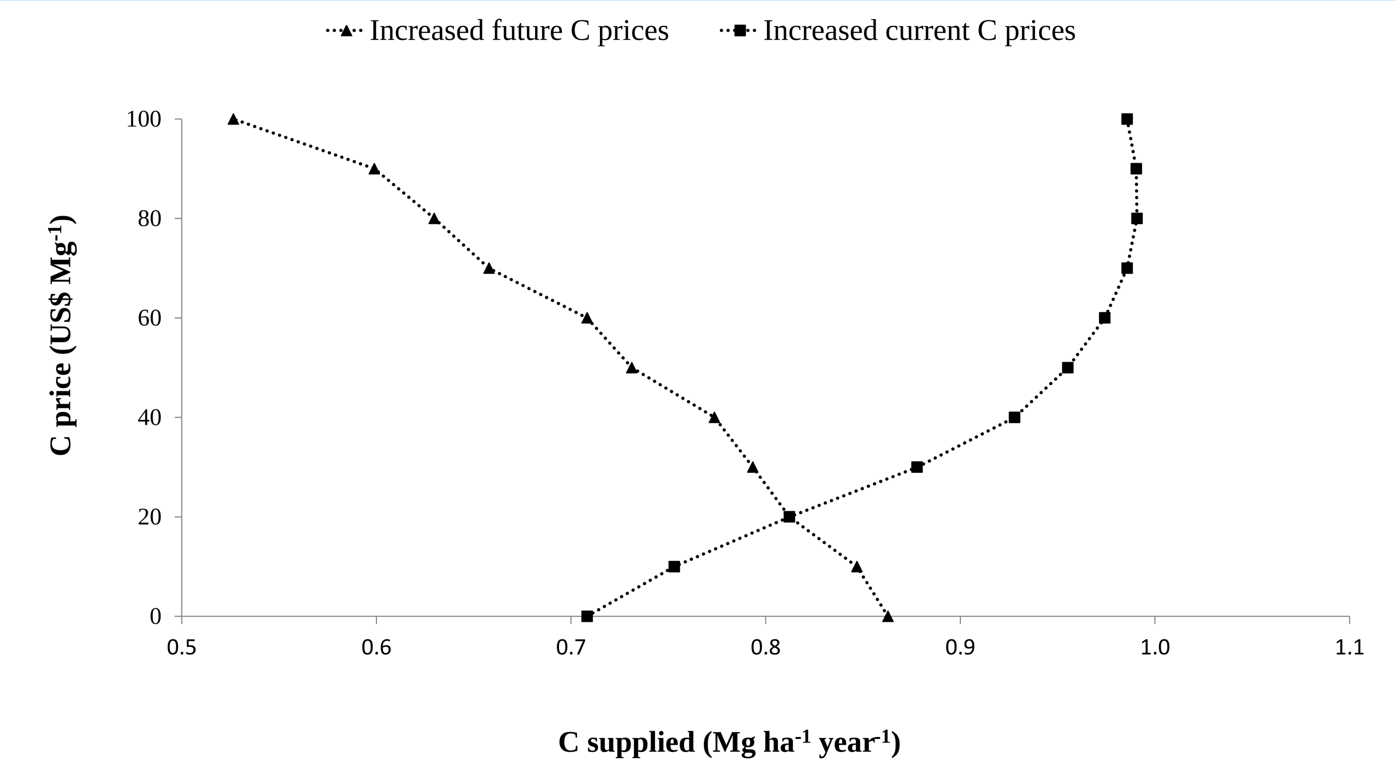
APPLICATION TO LOBLOLLY PINE STANDS US SOUTH

- Assuming a P_c= \$20 Mg^{-1} and optimal rotation age=27 years.
- A landowner should let the forest stand grow one more year (age 28) as long as LEV_{k+1} < \$2778.9 ha^{-1}.
- At age 26, he should have to let the stand grow until age 27 if LEV_{k+1}< \$3078.0 ha^{-1}.
- Optimal rotation age should be 26 years if \$3078 < φ <\$3375.9 ha^{-1} and 27 years if \$2778.9 < φ < \$3078.0 ha^{-1}.

Table 1 LEV and optimal rotation age

Age	$LEV(t)$	$\varphi(t)$
	\$US ha^{-1}	
23	2615.4	3983.5
24	2644.7	3676.2
25	2664.4	3375.9
26	2676.0	3078.0
27	2680.3	2778.9
28	2678.3	2475.9

SUPPLY OF CARBON AND IMPLICATIONS



- Increased current prices of carbon would increase the supply of carbon due to increased current optimal rotation ages.
- For prices equal and higher than \$80 Mg^{-1}, marginal supply of carbon sequestered becomes negative.
- Paying higher subsidies for sequestering carbon would not necessarily imply higher quantities of sequestered carbon compared to lower subsidies.
- Thus, forest sinks should be considered as one of many options to combat climate change in the U.S. Cost of carbon sequestration may be decreased by changing the management regime or choosing different tree species
- With higher future carbon prices, a forest landowner would be encouraged to reduce the supply of sequestered carbon sequestered.
- Future timber crops with longer harvest ages will become more profitable.
- Early depletion of existing forests due to incentives may increase the amount of carbon in the atmosphere and decrease non-timber benefits.

For further details of the model, please contact Andres Susaeta: asusaeta@ufl.edu