Mississippi Alluvial Valley Case Study:

Afforestation and Other Options

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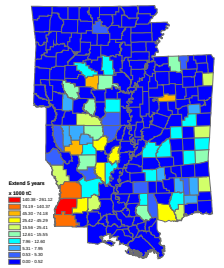
Funding from Winrock International, US EPA, US DOE
Thanks to Ralph Alig, Sandra Brown, Brian Murray, Jonathan Winsten and others for comments

Outline

- Overview of models for economic analysis of carbon sequestration potential
- Potential implications of plantation establishment in the Southern US
- Potential sequestration from aging and changing management.
- Conclusions and Discussion

Overview of Models



- Econometric Land Use Models
  - Widely used by economists to estimate factors influencing land use changes.
  - Examples: Hardie and Parks (1997); Stavins (1999); Plantinga et al. (1999); Lubowski et al. (2004)
  - Pro's:
    - Closely tied to data & empirically estimated; Allows estimation on uncertainty;
    - Empirical techniques can be used with many scales, i.e. county level or lower level of data
    - Provides opportunities to understand spatial dimensions of sequestration.
  - Cons:
    - Do not allow price response.
    - Do not model inventory.
    - Focus on land use change, do not typically allow management responses.

Overview of Models

- Market optimization models
  - Also widely used by economists to simulate market behavior. Built on behavioral assumptions about how market actors respond to economic incentives.
  - Examples: Adams et al. (1993); Adams et al. (1999); Murray et al. (2004); Sohngen and Mendelsohn (2003); Sohngen and Brown (2004).
  - Pro's:
    - Capture market equilibrium adjustments to policy shifts.
    - Capture interactions across regions as market prices change.
    - Manage forest stocks & model management adjustments.
  - Cons:
    - Regions are often highly aggregated.
    - Typically deterministic

Comparison of Cost Estimates South Central US

		Stavins (99)	Lee et al (04)	Sohngen et al (03)
Tg C Eq. per year	$50 ($55)	59.8	66.4	21.9
	$100 ($110)	94.8	106.1	56.4
Afforestation %	$50 ($55)	100%	48%	52%
	$100 ($110)	100%	59%	52%
Tg C Eq. per ha/yr	$50 ($55)	3.4	4.5	Not provided
	$100 ($110)	3.4	3.5	2.7

Forestland Area Results

Study Region: AR, LA, MS

- Historically, nearly 400,000 acres per year have converted to planted pine
  - From agriculture, natural pine, and upland hwds
- Upland hardwoods have increased due to afforestation

	1980's	1990's	Total Change Between Inventories	**Annual Change**
		Acres		
Planted Pine	4,207,946	6,977,978	2,770,032	**395,719**
Natural Pine	18,181,010	17,114,901	(1,066,109)	**(152,301)**
Upland Hwds	14,958,808	15,068,980	110,172	**15,739**
Total area (non Bottomland Hwds)	48,058,273	50,642,826	2,584,553	**369,222**

Source: USDA FIA

Potential Implication of Plantation Establishment in the US South

Carbon Sequestered in Stands – late 1990's

	Planted Pine	Natural Pine/ Oak Pine	Upland Hardwoods
	Mg Carbon per hectare		
Arkansas			
High Site[1]	**48.6**	**59.5**	**79.5**
Medium Site[2]	**39.0**	**50.5**	**61.9**
Low Site[3]	**29.6**	**42.2**	**54.5**
Louisiana			
High Site	**55.1**	**61.5**	**72.5**
Medium Site	**37.0**	**49.3**	**55.0**
Low Site	**20.5**	**31.2**	**48.2**
Mississippi			
High Site	**44.6**	**64.7**	**71.0**
Medium Site	**31.1**	**47.1**	**55.5**
Low Site	**26.5**	**31.0**	**44.5**

Carbon Sequestered in Pine and Hardwood Establishment

	Smith, Heath, Jenkins			Brown and Schroeder		
	Hardwood	Loblolly	Net Diff.	Hardwood	Loblolly	Net Diff.
	Tons Carbon Per Hectare					
Assume Harvests occur in both						
45 yr	55.2	45.1	**10.2**	53.9	45.7	**8.2**
90 yr	57.4	50.0	**7.4**	55.1	53.2	**1.8**
Assume Harvests occur only in loblolly pine						
45 yr	55.2	45.1	**10.2**	53.9	45.7	**8.2**
90 yr	59.8	50.0	**9.8**	70.4	53.2	**17.2**

What may happen to carbon balance over next 30 years under alternative land use change scenarios?

- How could pine plantation establishment influence carbon balance?
- Could incentives for natural hardwood and pine preservation increase carbon sequestration?

Econometric forest land-use model

- Adopt logistic modeling approach suggested by Hardie and Parks (1997), Plantinga et al. (1999), etc.
  - Integrate FIA data and focus on forestland types.
- Estimate model for 1980's – 1990's, and use econometric estimates for projections over future growth in rental rates.

Data

State	Years Collected
Arkansas FIA	1988,1995
Louisiana FIA	1974,1984,1991
Mississippi FIA	1977,1987,1994
All states NRI	1982, 1987,1992,1997

Forest Types Considered:

- Planted Pine
- Natural Pine & Oak-Pine
- Upland Hardwood (Bottomland hardwood not included in analyssis
- Forest area data obtained from USFS Southern Forest Experiment Station website.

Agricultural Types Considered:

- Agricultural land aggregated (cropland only)
- Cotton, Corn, and Soybeans used to estimate annual net returns above variable costs (“Rent”)
- Prices, costs, etc. obtained from USDA Economic Research Service.

Parameter Estimates

	Ln(PP/AG)		Ln(NP/AG)		Ln(HW/AG)	
	Param	SE	Param	SE	Param	SE
Constant	-10.506	5.571	-19.451**	4.193	-26.399**	4.182
TOTAL	**0.257****	**0.092**	**0.344****	**0.069**	**0.395****	**0.069**
D80	0.369	0.455	0.529	0.343	0.007	0.342
PPRENT	**0.058****	**0.010**	**-0.010**	**0.007**	**-0.028****	**0.007**
NPRENT	**-0.012**	**0.016**	**0.038****	**0.012**	**0.021**	**0.012**
UHWRENT	**-0.088****	**0.020**	**-0.041****	**0.015**	**0.027**	**0.015**
CROPRENT	**-0.013****	**0.003**	**-0.017****	**0.002**	**-0.016****	**0.002**
DELTA	-2.195**	0.635	-1.966**	0.478	-1.272**	0.477
HIFARM	-3.461**	0.505	-2.842**	0.380	-3.208**	0.379
DENS	**-0.007****	**0.002**	**-0.005****	**0.002**	**-0.004****	**0.002**
LAT	**0.270**	**0.162**	**0.519****	**0.122**	**0.699****	**0.122**
PPHI	0.227	2.528	4.387*	1.902	4.321*	1.897
NPHI	1.821	1.973	2.589	1.485	0.492	1.481
NPAVSI	0.421*	0.170	1.653**	0.128	0.312*	0.127
UAVSI	-0.014	0.158	-0.116	0.119	1.441**	0.118
PPLLSL	2.317	1.415	-2.779**	1.065	-3.233**	1.062
NPLLSL	4.185	2.943	5.630*	2.215	2.183	2.209

Baseline Predictions for 1990's

	Baseline Estimated		FIA Data	
	Hectares	Percent	Hectares	Percent
Planted Pine	2,164,500	9.3%	2,825,092	12.1%
Natural Pine	7,672,161	32.9%	6,929,110	29.7%
Upland Hardwood	6,836,744	29.3%	6,100,802	26.2%
Agriculture	6,636,046	28.5%	7,454,447	32.0%
TOTAL	23,309,450	100.0%	23,309,450	100.0%

Baseline Projections

	Historical Conditions			Predicted Future	
	1980's	1990's	**Annual Change**	2030	**Annual Change**
	Thousand Hectares				
Planted Pine	1,704	2,825	**160**	6,755	**135**
Natural Pine	7,361	6,929	**-62**	6,600	**-35**
Upland Hwds	6,056	6,101	**6**	4,454	**-69**
Total Forest Area (Non Bottomland Hwds)	15,121	15,855	**105**	17,809	**31**

Assumptions to 2030:

Crop rents fall at 1% per year

Planted pine rents rise at 1% per year

Natural pine and *hardwood* rents rise at 0.5% per year

Land Use and Carbon Projections

(Baseline: Planted pine rents grow at g = 1.0%)

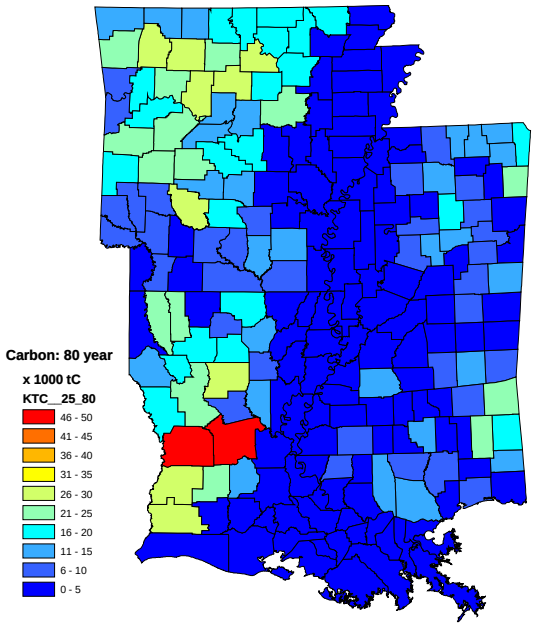
	2000	2010	2020	2030	**Ann. Chg.**
			Million Hectares		
PP	2.7	3.8	5.2	6.8	**135**
NP	7.6	7.6	7.2	6.6	**-35**
UHW	6.5	5.8	5.1	4.5	**-69**
Total	16.9	17.2	17.5	17.8	**31**
	Forest Carbon Stock: Tg Carbon (Million metric tons)				
PP	98.6	102.3	177.7	249.9	**5.0**
NP	468.5	372.3	334.1	322.7	**-4.9**
UHW	397.9	323.8	272.8	231.3	**-5.6**
Total	965.0	798.4	784.7	803.9	**-5.4**
	Total Carbon Stock (Forest + Products): Tg Carbon (Million metric tons)				
PP	98.6	132.7	214.3	311.3	**7.1**
NP	468.5	462.2	461.2	470.5	**0.1**
UHW	397.9	376.7	348.9	320.1	**-2.6**
Total	965.0	971.7	1024.4	1101.8	**4.6**

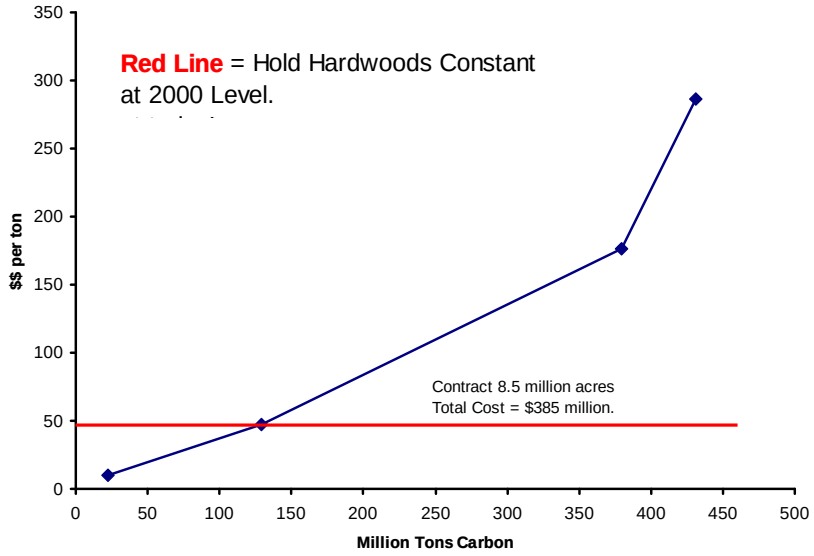
Comparison Across Results

	Baseline	Hi Plantation Est. Rates	Subsidize Hardwoods	Subsidize Hwd/ Nat. Pine
		Thousand Hectares/yr		
PP	135	251	78	54
NP	-35	-92	-59	-37
UHW	-69	-117	4	8
Total	31	42	24	25
	Forest Carbon Stock: Tg Carbon (Million metric tons)/yr			
PP	5.0	8.4	3.2	2.5
NP	-4.9	-6.6	-4.6	-3.5
UHW	-5.6	-7.7	-1.7	-1.8
Total	-5.4	-5.9	-3.1	-2.7
	Total Carbon Stock (Forest + Products): Tg Carbon (Million metric tons)/yr			
PP	7.1	10.4	5.3	4.6
NP	0.1	-1.5	-0.7	0.2
UHW	-2.6	-4.1	-0.1	-0.2
Total	4.6	4.8	4.5	4.6

Marginal Cost of C Sequestered

Total tons stored; $$ per ton





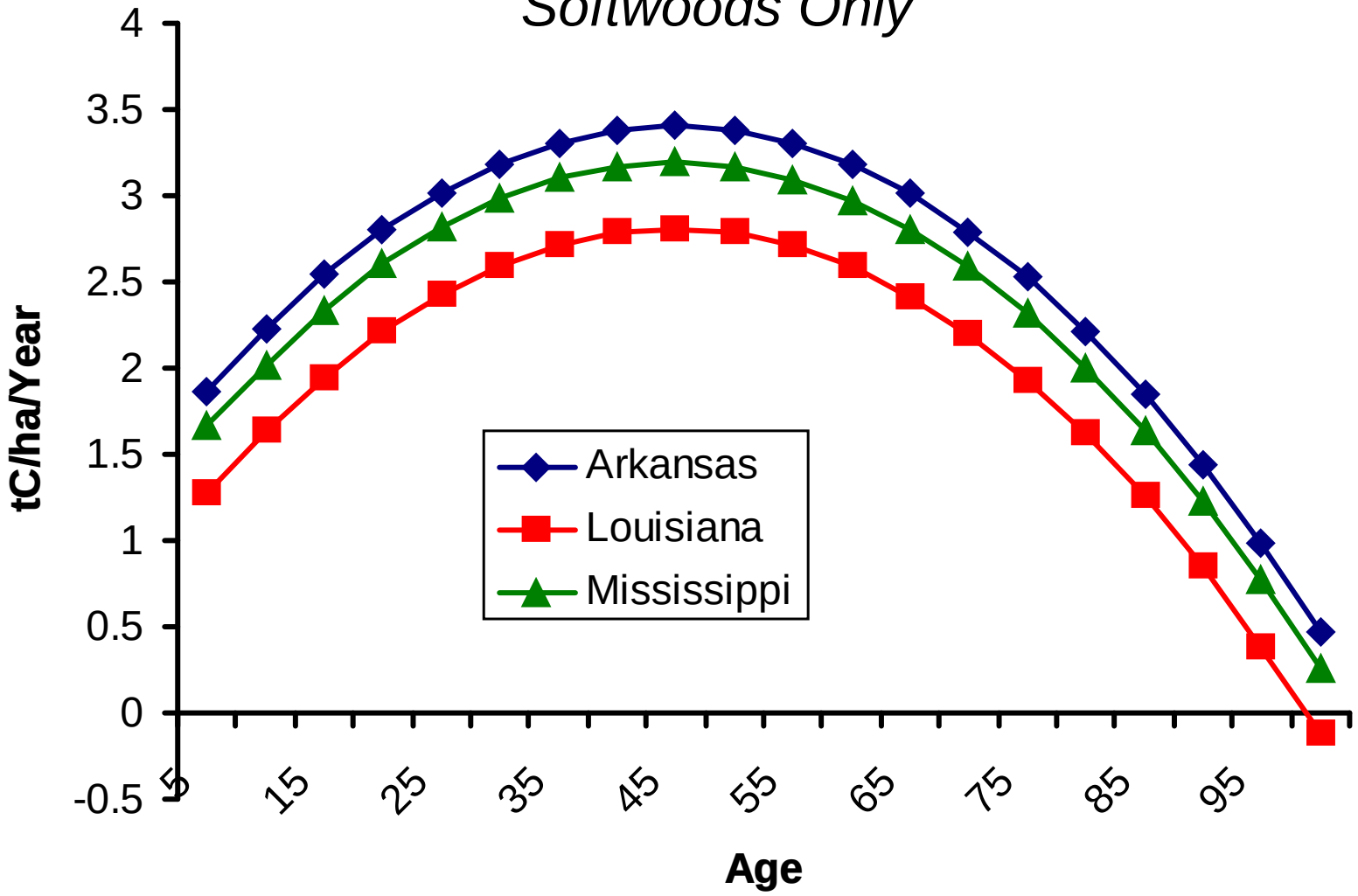
Other Alternatives

- Increase Rotation age on forests that are managed intensively.
  - WHO: Industrial land and TIMOS controlled land where evidence of age based mgmt. is more clear.

- Increase forest management
  - Use nitrogen
  - Thinning to increase merchantable yield and to increase market storage, etc.
  - WHO: Non industrial owners where less evidence of movement towards intensive management.
    - Role of TIMOS?

Aging Timber:
Annual Production vs. Timber Age

Regression based on FIA data for counties in AR, LA, MS
Softwoods Only



Fertilizers, Herbicides, Thinning

- According to Rogers and Munn (2002), 71-73% of industrial (industry and timber management companies) land that is regenerated each year undergoes chemical treatments.
- Siry (2002) reports that fertilizers and herbicides can increase merchantable timber yield 15 – 30%.
  - Unclear if they will also increase total biomass on-site.
- Large Adoption of fertilizers and herbicides on industrial and highly managed land.
  - Less intensive on natural sites.
- Potential exists to expand management on non industrial land
  - Planting of natural pines
  - Fertilizer and herbicide applications on newly planted sites.

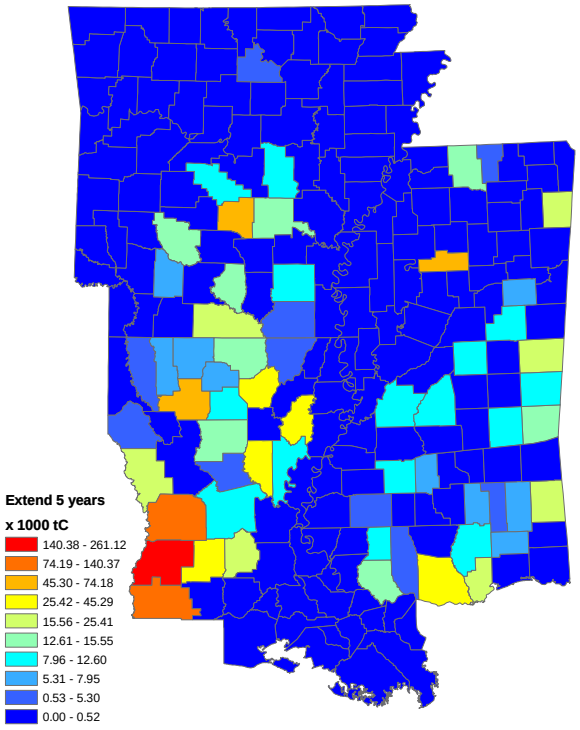
Aggregated Estimates of Sequestration Costs

*Based on County-By-County Analysis of Potential Hectares that **could** be treated according to FIA data.*

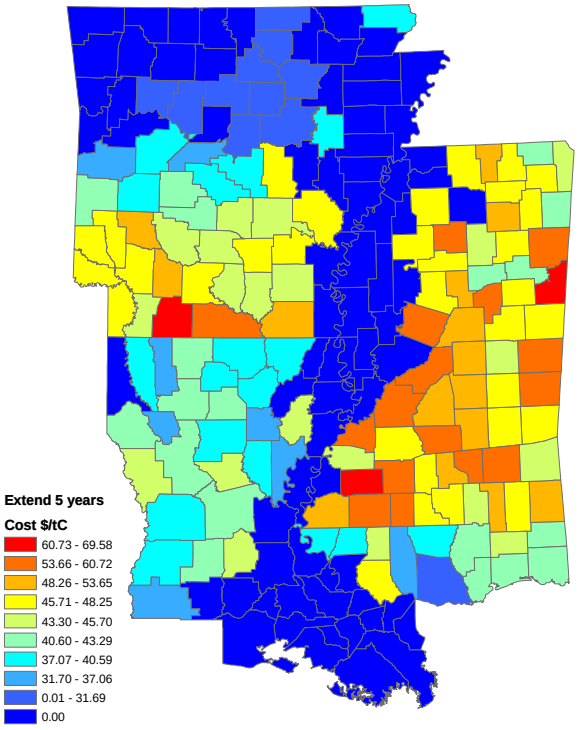
	Hectares	Million Tons	Million $$	Ton per ha
Regeneration	320,123	2.37	$99.18	7.40
Thinning	532,623	6.43	$404.05	12.07
Aging	150,115			
5 Years				5.39
		0.81	$67.42	
10 Years				7.46
		1.12	$284.99	
15 Years				8.06
		1.21	$673.90	

Spatial Distribution of Aging Timber 5 Year Holding Time

1000 Tons Carbon

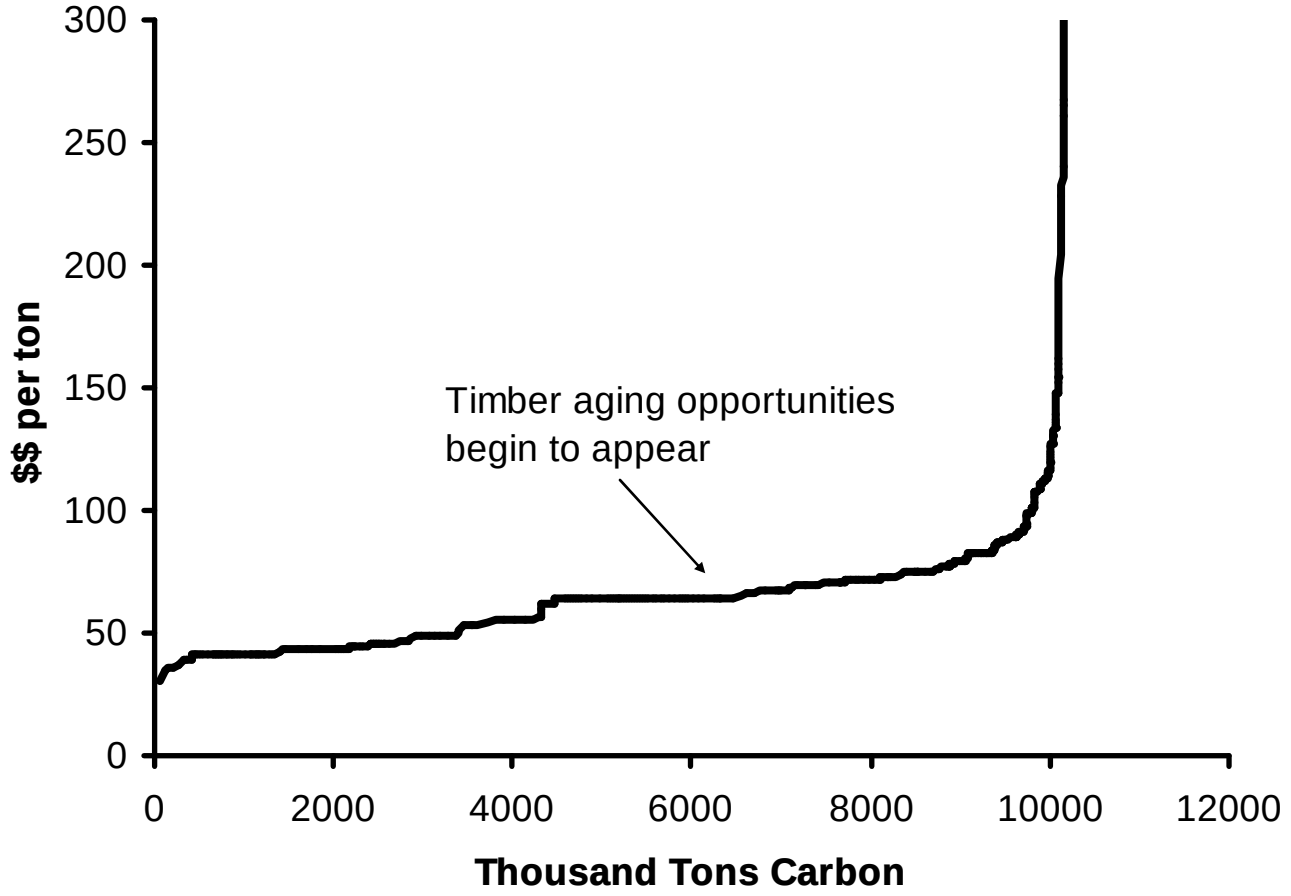


$/T Carbon



MAC for Increasing Mgmt and Holding Timber in Southern Pine

AR, LA, MS



Results

- Econometric and optimization models lead to different results on carbon sequestration
  - Range in costs is substantial, particularly when the source of the change is considered.
    - Afforestation + Management
    - Inclusion of soils in optimization models (although small effects)
    - Price effects
  - No economic principles suggesting that one method should lead to higher or lower costs.
  - Econometric results put more emphasis on land use change, whereas optimization models put equal emphasis on management and land use change.

Results

- Future plantation establishment may increasingly involve hardwood conversions
  - 1 hectare of pine plantations established eliminates:
    - 0.26 hectares of natural pine
    - 0.51 hectares of hardwoods
    - 0.23 hectares of agriculture
  - Leads to carbon emissions for above-ground carbon of approximately **5.4 million** tons per year in AR, LA, and MS.
    - 1 acre of pine plantation establishment increases carbon storage on-site by 37 tons per hectare, but reduces carbon elsewhere by 50 tons per hectare established, suggesting a net loss of approximately **13 tons** per hectare established.
  - When products are considered, plantation establishment leads to net sequestration of approximately **4.6 million** tons per year in the region.

Results

- Faster plantation establishment could lead to greater emissions from land activities.
  - Harvesting, however, offsets losses when product storage is considered.
  - ***Explanation: Shift more land away from natural types and into plantations, although they do increase the overall area of land in forests.***
- Allowing timber to age and increasing management appear to be fairly expensive alternatives (i.e. >$40 per ton)
  - Could be difficult to determine baseline with both, although aging could be esier on industrial land while management could be easier on NIPF land.
  - Management may be cheaper than estimated if alternative contracts are considered, i.e. benefits shared.