Alternative Methods for Establishing Carbon Baselines: Afforestation of Mississippi Bottomland Hardwoods

Presented at Forestry and Agriculture Greenhouse Gas Modeling Forum

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Shepherdstown, WV
October 9, 2002

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Funding and collaborators

- *Funded by US EPA, Non-CO2 Greenhouse Gas and Sequestration Branch*
- *Collaborators*
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  - *EPA: Ben DeAngelo and Ken Andrasko*
  - *US Fish and Wildlife Service: Kevin Sloan*
  - *Others: Brent Sohngen (Ohio State), Bruce McCarl (Texas A&M), Nick Stone (Va Tech) , Jim Henderson (Stratus)*

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Policy Context

- Offset projects via private GHG markets and/or public programs
- Possibly only “additional” GHGs eligible
- Additionality requires an estimation of GHG profile without the project (‘baseline’)
- LULUCF => baseline is primarily about projecting land use change under BAU (no project) conditions

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Baseline Adjustment

- Assume current land use (cropland/conventional management) is in carbon steady state
  - Net carbon gains only through land use change
- Baseline Carbon Sequestration in Year t

$$BC_T = \Sigma\Sigma\ L_{id}C_i(t\text{-}d)$$

L_{it} = baseline change to land use i in year d < t

$C_i(t\text{-}d)$ = carbon sequestration rate in use i after (t-d) periods

Baseline Adjustment: Illustrative Example

- Project Activity: afforestation
- Project size: 10,000 acres
- Baseline rate of afforestation: 0.67%/yr
- Sequestration rate: 1 ton/ac/year (fixed)
- Project Vs Baseline
  - Project sequestration rate = 10,000 tons/yr
  - Baseline sequestration rate
    - Yr 1 = 67 tons/yr
    - Yr 2 = 134 tons/yr,....
    - Yr 60 = 4,000 tons/yr

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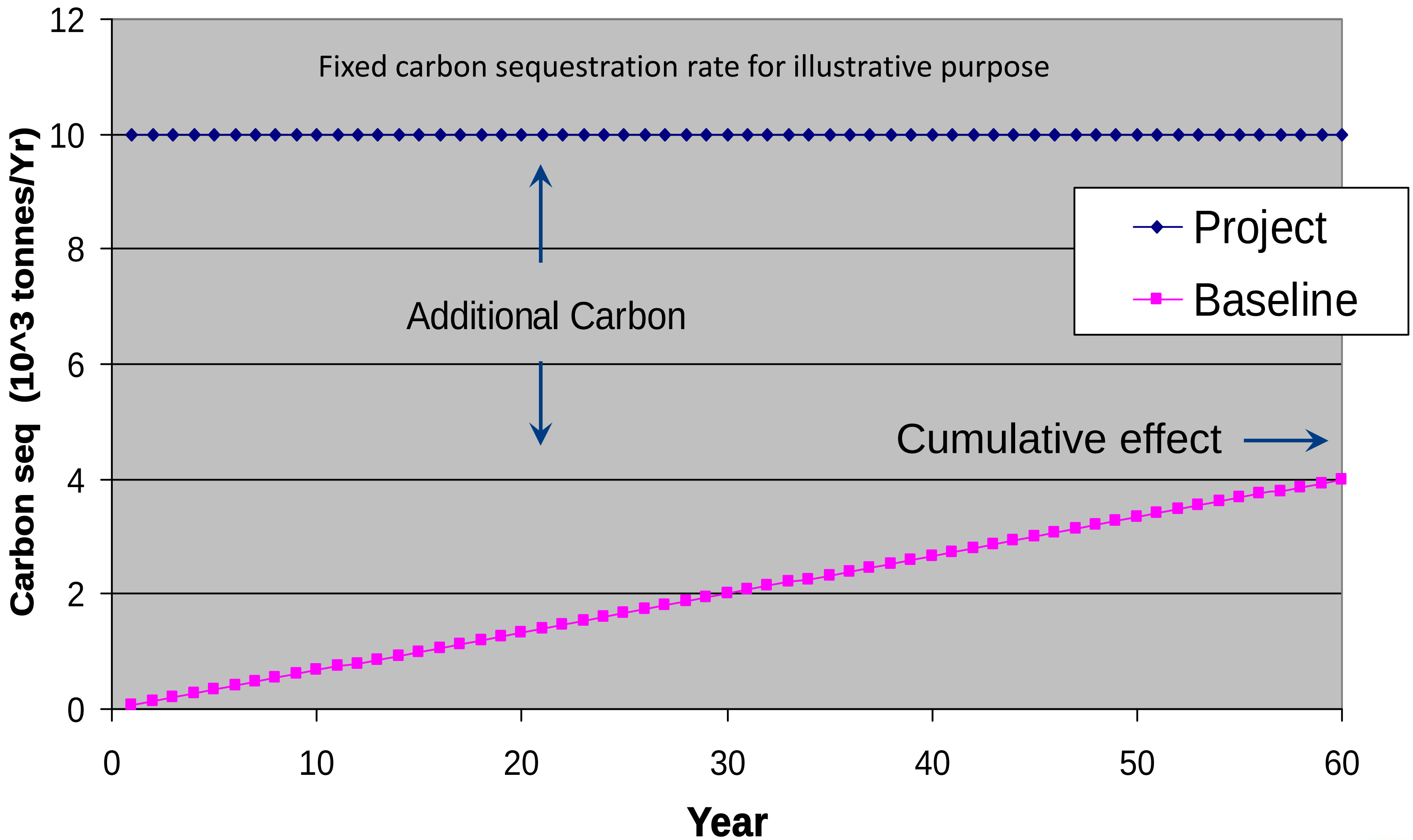
Project, Baseline, and Additional Carbon



Effect of Timing on Baseline/Additionality Factor

- Q: What portion of project GHG benefits should be deducted as not additional (i.e., baseline portion) ?
- Baseline would have evolved over time; project happens now => GHG payments need to account for this

$Z = (1+g)^T$ = cumulative baseline land use change by end of project (Year T)

Baseline Adjustment Factor (scalar)

$$BAF = Z/(1+r)^{T/2}$$

Example from last slide: Z = 0.40, T=60, set r = 0.04

BAF = 0.123 => Reduce payments by 12.3%

Approaches to projecting land use change

- Methodological angles
  - Trend extrapolation of available natural resource data
  - Land Use Modeling
    - Optimization
    - Econometric
    - Other

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Trend Extrapolation

- Apply recent land use transition data from publicly available sources to proxy for future land use transitions in the project area
  - NRI, USFS/FIA data
- Advantages
  - Comprehensive coverage (within US)
  - Expedient for non-technical project developers to apply
- Disadvantages
  - Low resolution – pre-existing trend data at high levels of aggregation (e.g., nation, region, state)
  - No explanatory variables (except region of location)
  - No statistical properties to work with (e.g., std errs)

Modeling: Econometric Approaches to Land Use Change

- Basic model
  - Change land use from i to j if $\Pi_i > \Pi_j$
  - $Yij = F(X\beta) + e$
- Alternative Approaches/Scales
  - Area-based models (e.g., county-level land allocations)
  - Plot-level econometrics
  - GIS: pixel-level spatial econometrics
- Examples: Alig; Stavins and Jaffee; Parks and Murray; Hardie and Parks; Plantinga and Ahn; Lubowski et al; Pfaff et al; Bockstael, Irwin, Bell, …

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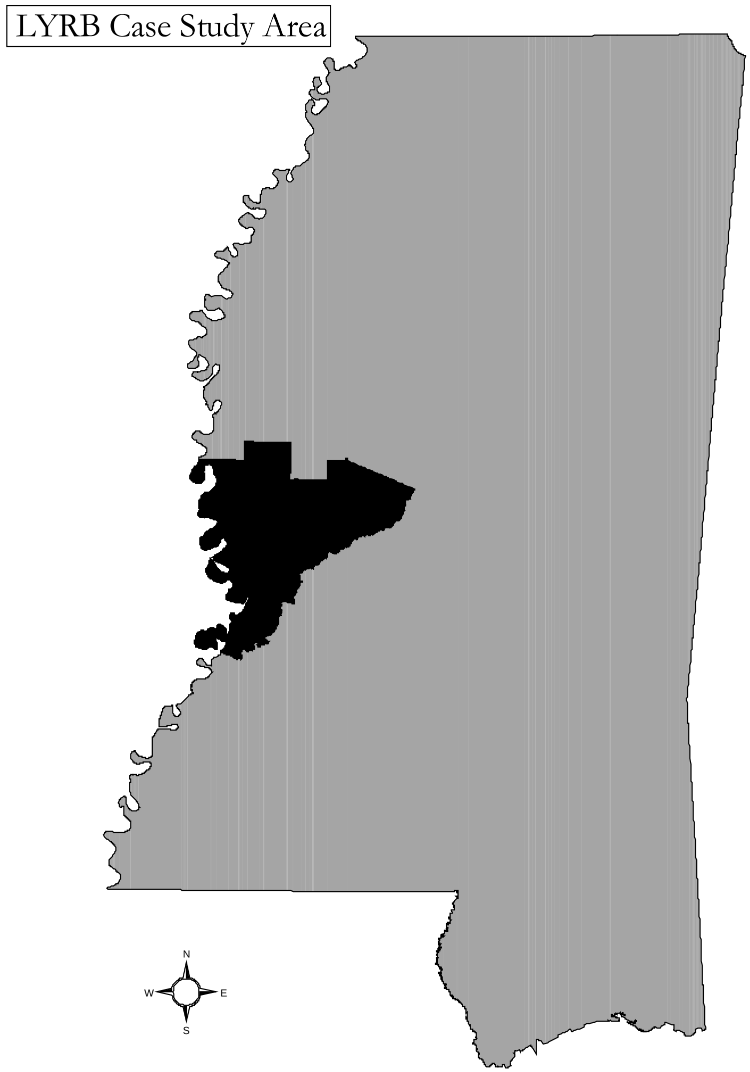
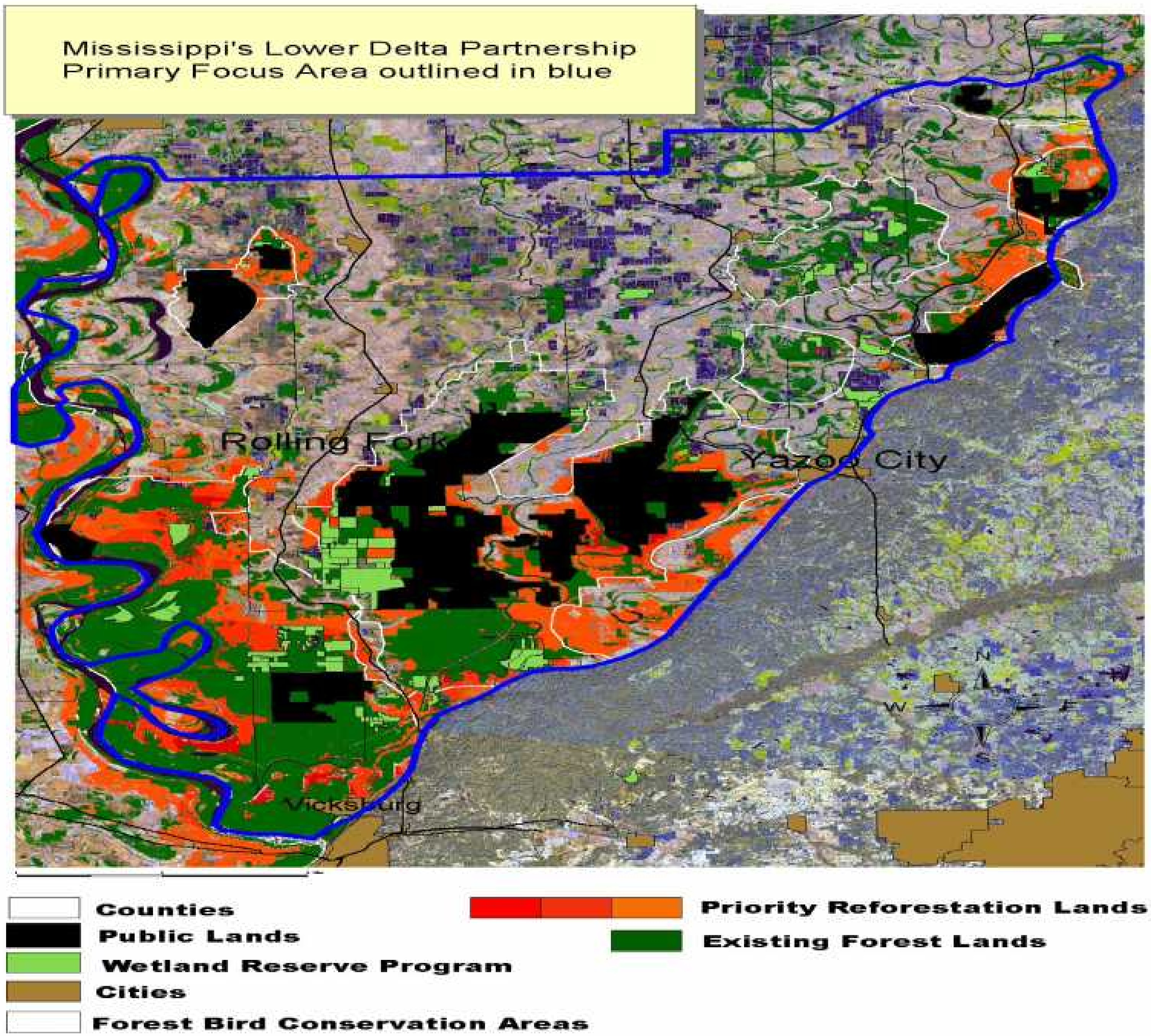
Sequestration Case Study:
Forest Restoration in the Lower Yazoo River Basin, Mississippi

Case Study Dimensions

- Location: 4 counties in west-central Mississippi
- Project Activity: Convert marginal cropland to bottomland hardwood forest
  - Marginal = in 2-year flood plain
- Forest Management regimes
  - Commercial forestry
  - Preservation forestry

Lower Yazoo River Basin, MS




Mississippi's Lower Delta Partnership
Primary Focus Area outlined in blue
Rolling Fork
Yazoo City
Vicksburg
N
W
S
Counties
Public Lands
Wetland Reserve Program
Cities
Forest Bird Conservation Areas
Priority Reforestation Lands
Existing Forest Lands

Analysis Steps

1. Create GIS database for project area
2. Estimate project carbon using forest carbon model (FORCARB), adjusted for local forest conditions
3. Carbon credit adjustments
   - Leakage (FASOM simulations): 20-40%
   - Baseline/additionality (see below)
4. Estimate financial returns to project
   - Carbon
   - Timber
   - Subtract current returns to agriculture

Baseline Approach 1: Use existing county-level econometric land use estimates for region

- Baseline afforestation rate at county-level based on econometric projections [Plantinga and Ahn (2002)]
  - ~ 0.6% per yr for study area, decline over time
  - Essentially same for all Ag land in 4-county region
- Estimated Baseline Adjustment factor
  - Baseline Adjustment Factor (BAF) = [**0.129]**

=> Carbon credits reduced by 12.9 % to account for baseline/additionality

Potential Shortcomings of Baseline Approach 1

- Aggregate model may not capture specific inter-county differences in a well
  - Variation in predicted afforestation rates is based on variation of economic & biophysical factors across all counties in South
    - Not much variation in county-level averages between Issaquena, Sharkey, Warren, and Yazoo counties
    - Therefore the predicted rates don't differ much with this model
- Does not capture intra-county differences at all

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Baseline Approach 2: Estimate County-level LU Trends Using National Resources Inventory (NRI) Data

- Data
  - 1982-1997, 5 year increments
  - 1,371 plots in 4 county region
  - 58 LU categories (collapsible)
- Method
  - Compute county-specific land use transition matrices (5,10, 15 year) using historical data
  - Apply historical afforestation rate (1982-97) as future rate projection

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NRI Land Use Transition Matrix for Issaquena County: 1982-1997

1982 1997	Cropland	Pastureland	Forestland	Other land
Cropland	119,500			16,300
Pastureland		2,700		900
Forestland	9,100		110,200	2,200
Other land	5,200		400	12,900
CRP Land	3,100			

1982-1997 Crop-forest conversion rate = [9,100/136,900] = 0.066

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Baseline Approach 3: Multivariate regression analysis of NRI plot data

- Dependent variable (Y): Discrete change in land use over 5, 15 year time period
- Explanatory variables (X): county dummies, soil characteristics, elevation, other suitability factors
  - Assume market prices do not vary within 4-county region
- Estimate Discrete Choice Model of Y on X to parameterize relationship of plot characteristics on land use change

Logit Results: NRI Plot Data

Dependent Variable Cropland conversion to forest, 1982-1997

Independent Variables	**Coef.**	**Std. Err.**	**z**	**P>|z|**
Issaquena	1.6555	0.9418	1.76	0.079
Warren	2.3292	0.9459	2.46	0.014
Yazoo	1.1898	0.9348	1.27	0.203
Flooding_freq	***1.2045***	***0.7584***	***1.59***	***0.112***
Constant	-4.3811	0.8455	-5.18	0

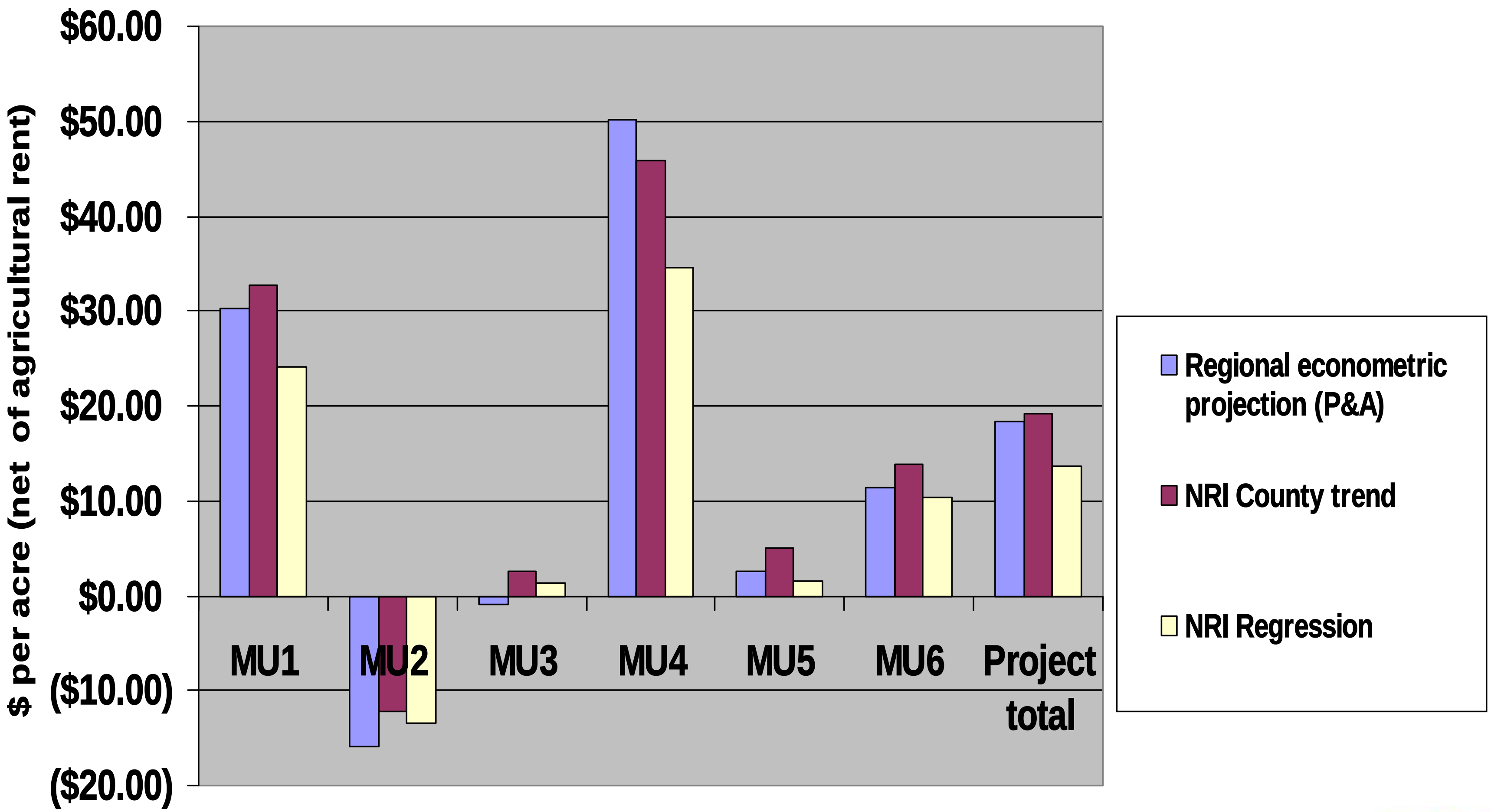
Number of obs	400	**Log likelihood**	-73.456
LR chi2(4)	12.35	**Pseudo R2**	0.0775
Prob > chi2	0.0149		

Effects of Changing Baseline Method on Baseline Adjustment Factor

MU	County	Acreage	Approach 1 Regional econometric projection (P&A)	Approach 2 NRI County trend	Approach 3 NRI Regression: County & Flooding effects
1	Issaquena	211	.129	.093	.216
2	Sharkey	343	.129	.020	.058
3	" "	1,262	.129	.020	.058
4	**Warren**	**1,999**	**.129**	**.180**	**.317**
5	Yazoo	967	.129	.058	.157
6	" "	2,126	.129	.058	.157

P&A is econometric estimate based on region-wide model of Plantinga and Ahn (2002)

Effect of Baseline Method on Project Net Economic Returns: $25/ton C price



Baseline Approach 4: Multivariate regression analysis of GIS pixel data

- Data: USGS National Land Cover Data Base (NLCD)
  - Resolution: 30 m^2 pixels
  - Time period: 1992-1999
  - Abundance of pixels (> 1 mm) needs to be aggregated for meaningful analysis
- Discrete choice model
  - Y: Pixel-level land use change
  - X: site characteristics, spatially defined variables (distance, spatial lags)
  - Spatial autocorrelation adjustments

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Comparison of Land Use Transition in LYRB: NLCD vs NRI data

	NLCD 92-99	NRI 92-97
LYRB % Cropland Retention 7 yr. period	98.81%	92.23%
LYRB % Cropland to Forest 7 yr. period	0.12%	4.09%
LYRB % Cropland to all other	1.07%	3.68%
LYRB % Forest Retention 7 yr. period	98.95%	98.35%
LYRB % Forest to Cropland 7 yr. period	0.32%	0.40%
LYRB % Forest to all other	0.73%	1.26%

Upshot: NLCD data indicate much less land use change than NRI

Modeling Implications ?

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Summary

- Additionality principle implies need for estimation of project carbon baselines
- Baseline estimation requires models of land use change (LUC) and GHG accounting
- More spatially refined LUC estimates are more costly to develop, but yield more precise estimates of baselines and the expected $ returns to a project.
- NRI data can provide good foundation for localized estimates.
- NLDC data could allow for more much more precision, but subtle LUC may be harder to detect and parameterize.