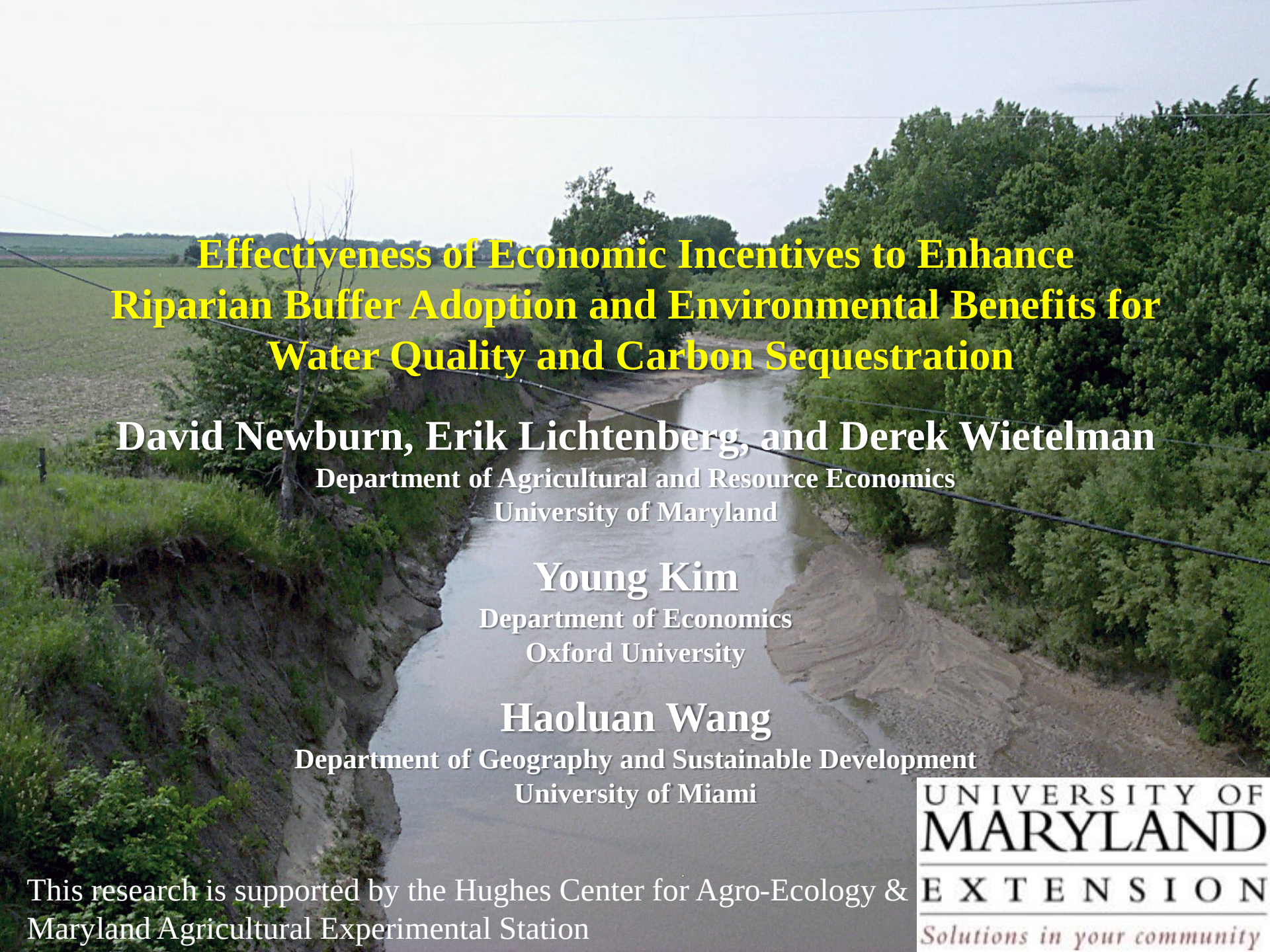

Effectiveness of Economic Incentives to Enhance Riparian Buffer Adoption and Environmental Benefits for Water Quality and Carbon Sequestration

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Economic Incentives for Riparian Buffers

- **Conservation Reserve Enhancement Program (CREP)**
  - Federal-state partnership started in 1997
  - Long-term contracts (10-15 years) for grass and forest buffers
    - Full installation costs
    - Signing bonus (HB991 Tree Solutions Now Act)
    - Annual payments based on soil rental rate and buffer maintenance

- **Maryland's Conservation Buffer Initiative**
  - MDA initiated pilot program in 2021
  - Shorter contracts (5-10 years)
  - Higher upfront payment (in lieu of annual payments)

Objectives and Approach

- **Goal**: Evaluate environmental outcomes under different policy scenarios
  - Program attributes affecting landowner enrollment
  - Overall program effectiveness

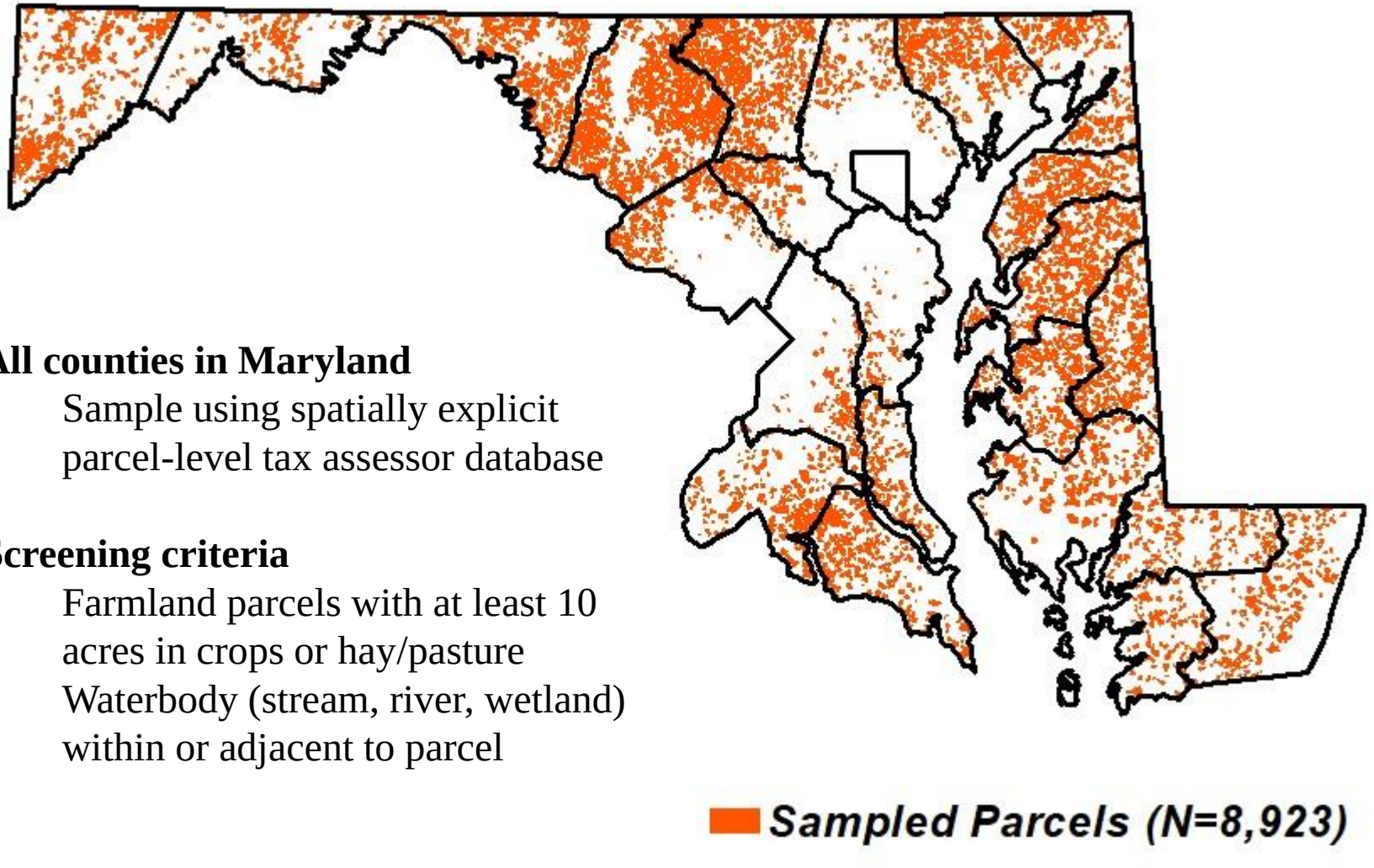
- **Policy scenarios**:
  - CREP (baseline)
  - MDA Conservation Buffer Initiative
    - Upfront vs. annual payments
    - Shorter contracts
  - Targeting bonus payments based on environmental benefits
  - CREP plus carbon offset payments

- **Econometric model**: Estimate farm-level spatial variation in probability of enrollment for installing forest and grass buffers using landowner survey

- **Integrated assessment model**: Site-specific environmental benefits for landowner enrollment for forest and grass buffers
    - Water quality (nitrogen and phosphorus reductions in Bay)
    - Carbon sequestration (forest buffers)

Part I:
Landowner survey &
Modeling proposed buffer incentive programs

Buffer Survey for Maryland Landowners



- **All counties in Maryland**
  - Sample using spatially explicit parcel-level tax assessor database
- **Screening criteria**
  - Farmland parcels with at least 10 acres in crops or hay/pasture
  - Waterbody (stream, river, wetland) within or adjacent to parcel

Survey Process

- Survey questionnaire development with collaboration and input from key experts and stakeholders
  - DNR (Anne Hairston-Strang)
  - MDA (Alisha Mulkey)
  - CBF (Rob Schnabel)
  - USDA FSA (Laura Pleasanton)
  - UME agents (Jim Lewis, Agnes Kedmenecz, Sarah Hirsh)

- Mailing in summer 2021
  - Letter provided instructions to participate in the online survey in Qualtrics
  - Unique ID and password to link to landowner parcel location

- Full sample of 8,923 rural landowners
  - Total of 1,530 survey respondents (1,420 online + 110 by mail)

Buffer Survey Data

- Riparian buffer history
  - Buffer acreage, year installed, cost-share received (yes/no), buffer type
- Farm-level management
  - Crop type acreages, % rented, farm income, livestock
- Landowner demographics and attitudes
  - Age, education, % income from farming
  - Attitudes toward farm support programs, government monitoring farm practices, taking on long-term risky investments
- Spatial site-specific parcel data
  - Land cover and area in riparian zone
  - USDA soil rental rate (SRR) based on dominant soil types

Proposed Buffer Program Attributes

Program attribute	What it means
Buffer type	**Type of buffer to be installed**. Options include: Grass buffer, forest buffer
Bonus payment	**One-time bonus payment ($ per acre) for enrolling in the program**. Options include: $200, $500, $1,000, $1,500 per acre
Annual payments	**Recurring annual payments ($ per acre)**. Options include: $100, $250, $500, $750 per acre
Contract length	**Number of years to maintain the buffer**. Options include: 5, 10, 15 years

- Assume minimum buffer width of 35 feet per program requirement
- Installation and maintenance costs are fully covered

Example: Proposed Buffer Program

- Installation costs and maintenance costs will be fully covered by the program, regardless of the buffer type offered in the program
- You will receive the one-time bonus payment **at the time you enroll in the program**
- The program requires a minimum buffer width of 35 feet

Program element	**Program X**
Buffer type	Grass buffer
Bonus payment ($/acre)	$500
Annual payments ($/acre)	$250
Contract length (years)	10

The payment schedule for **Program X** will look like the following "Example" table:

	Program X
Year 0 – Bonus payment ($/acre)	$500
Year 1 – Annual payment ($/acre)	$250
Year 2 – Annual payment ($/acre)	$250
Year 3 – Annual payment ($/acre)	$250
Year 4 – Annual payment ($/acre)	$250
Year 5 – Annual payment ($/acre)	$250
Year 6 – Annual payment ($/acre)	$250
Year 7 – Annual payment ($/acre)	$250
Year 8 – Annual payment ($/acre)	$250
Year 9 – Annual payment ($/acre)	$250
Year 10 – Annual payment ($/acre)	$250
	Contract ends

Would you enroll in **Program X**? (Choose one)

- ○ Yes – I would enroll
- ○ No – I would not enroll

Each landowner answers 4 randomly assigned program designs

Econometric Model on Program Enrollment

- **Site-specific probability of program enrollment**
  - Logit model used to estimate probability of enrollment in buffer program as a function of program attributes, landowner characteristics, and farm/parcel characteristics (Enroll=1, Not enroll=0)
  - Prob[Enroll] = *f* (program attributes, landowner and farm characteristics)

- **Program attributes**
  - Buffer type (forest vs. grass)
  - Upfront (one-time) bonus payment
  - Annual recurring payments
  - Contract length
- **Landowner characteristics**
  - Rented out, % farm income, farmer age, education, etc.
- **Farm/parcel characteristics**
  - Crop return (soil rental rate based on 3 dominant soils in parcel's buffer area)

Econometric Model Results

- Upfront bonus and annual payments both increase enrollment significantly
  - Tradeoffs between annual and upfront bonus payment suggest landowners have strong preference for upfront payments
- Contract length is not significant
- Farmer/parcel characteristics MORE likely to enroll
  - Current participation in CREP
- Farmer/parcel characteristics LESS likely to enroll
  - Higher quality land (i.e., higher soil rental rate)
  - High % farm income
  - Senior (Age > 65 years)
  - Opposition to property monitoring and/or tax-funded farm programs
- Unwilling landowners
  - Landowner types willing vs. unwilling to enroll
  - 46% of landowners chose not to enroll in any of the 4 randomly assigned proposed programs, despite payments offered higher than current CREP levels

Part II:
Integrated assessment model & Policy scenarios

Integrated Assessment Model: Water Quality

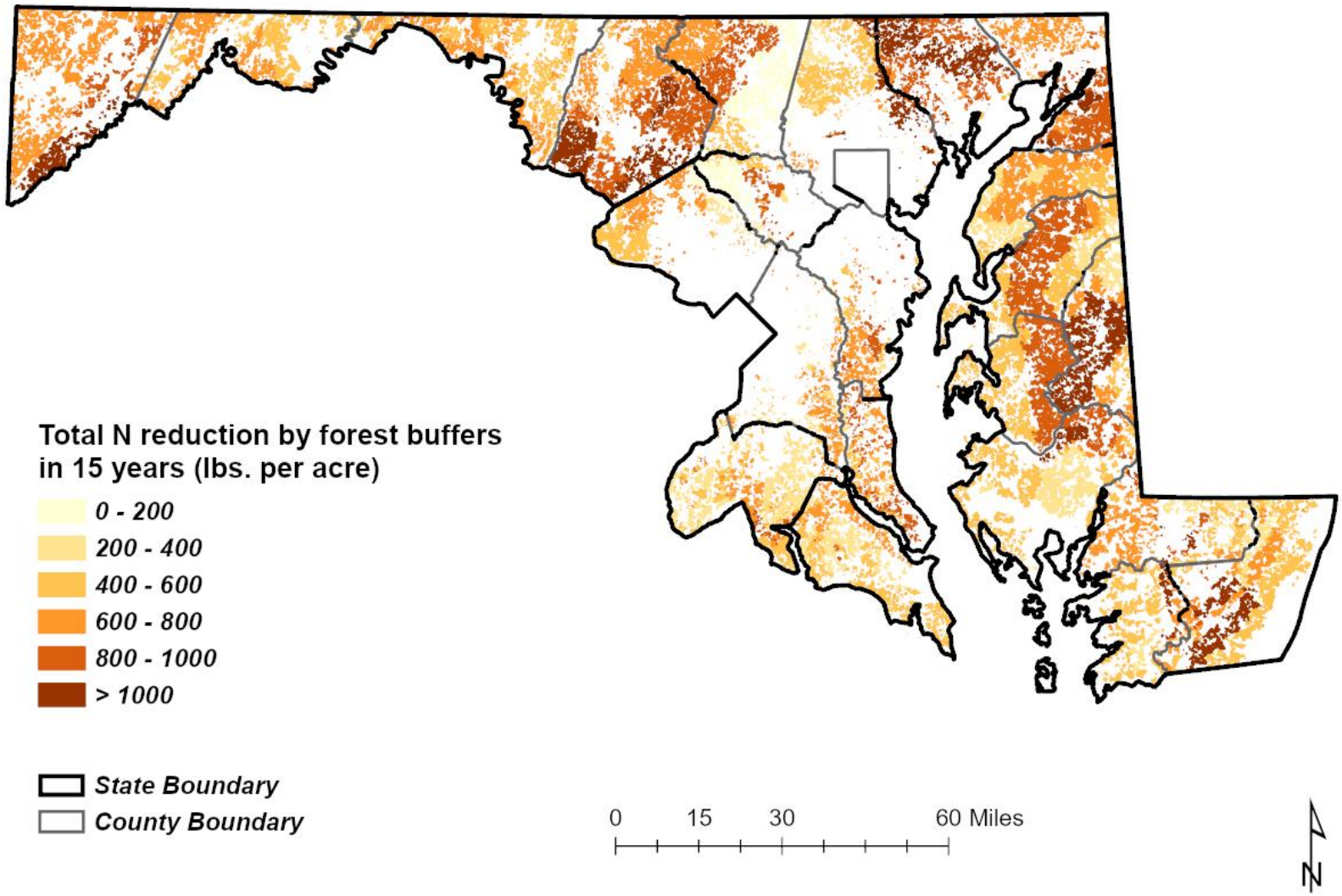
- **Buffer opportunities**
  - Identify riparian zone (35-foot width) without buffers using high-resolution land cover data (Chesapeake Conservancy)

- **Water quality model**
  - Parcel/farm-level estimates for nitrogen (N) and phosphorus (P) reductions for forest and grass buffers over specified contract length
  - Chesapeake Bay Watershed Model parameters
    - N and P loads for initial cropland and buffer type
    - Buffer practice efficiency on nutrient removal rates
    - Delivery factors from local watershed to the Bay

- **Environmental benefits for water quality**
  - Social cost of pollutant loads to the Bay estimated at $17.11 per pound N and $207.66 per pound P (Choi et al. 2020)

Nitrogen load reduction

Forest buffer for 15-year contract

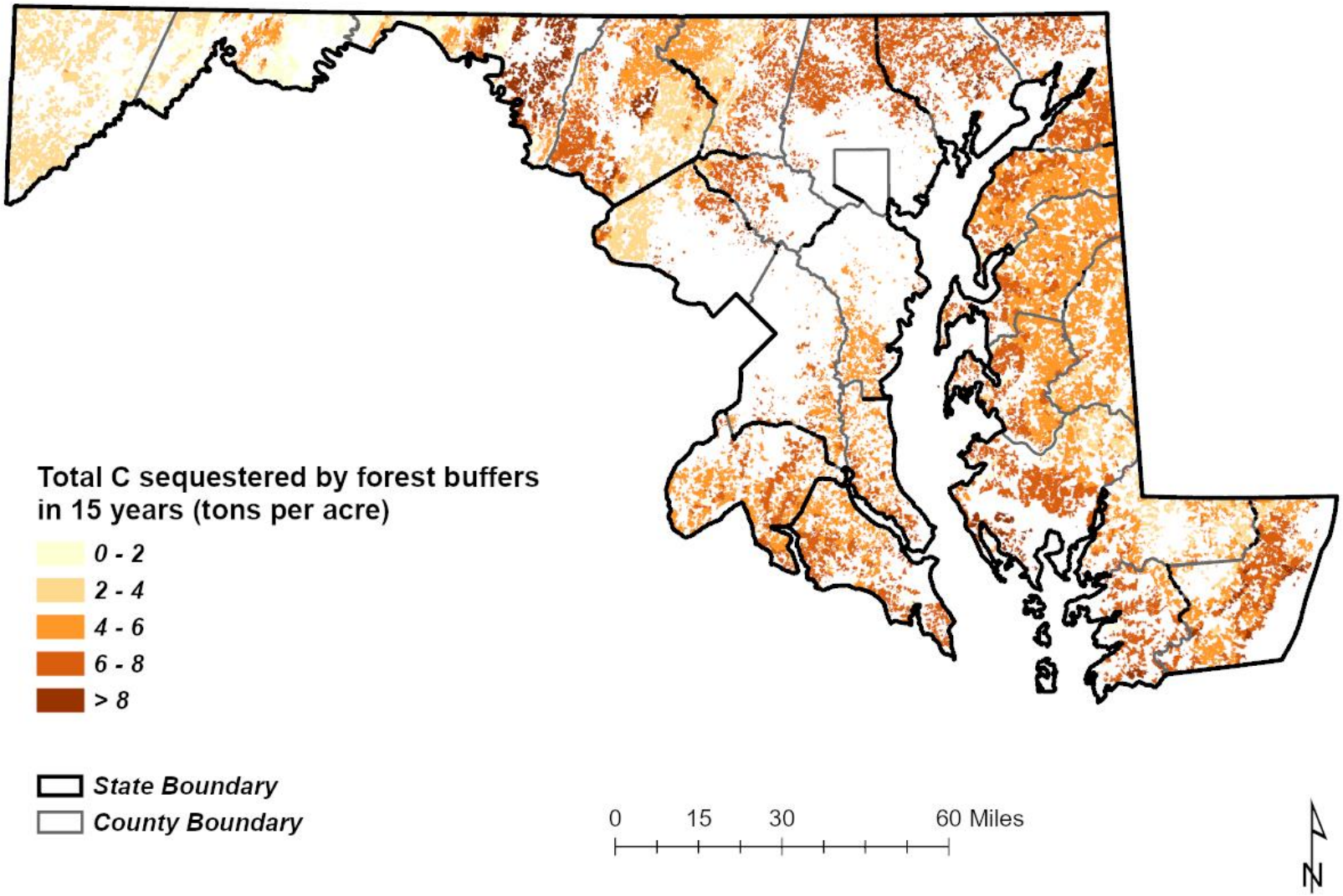


Integrated Assessment Model: Carbon

- **Carbon sequestration**
  - High-resolution forest carbon modeling for Maryland and northeast US (Hurtt et al. 2019; Lamb et al. 2021; Ma et al 2022)
  - Ecosystem Demography Model
    - Incorporates spatial and temporal variation in weather conditions (temperature, precipitation, etc.) and soil characteristics (depth, water retention, etc.)
    - Model estimates forest carbon storage (tons C per acre) at 30-meter resolution over time
  - Parcel/farm-level estimates of carbon sequestration for above-ground biomass in forest buffers over specified contract length (e.g., 15-year contract)
- **Environmental benefits of carbon sequestration**
  - Social cost of carbon estimated at $418 per ton C for permanent storage (Carleton and Greenstone 2022; EPA 2023), but discounted for buffer contract length (e.g., 15 years)

Carbon sequestration

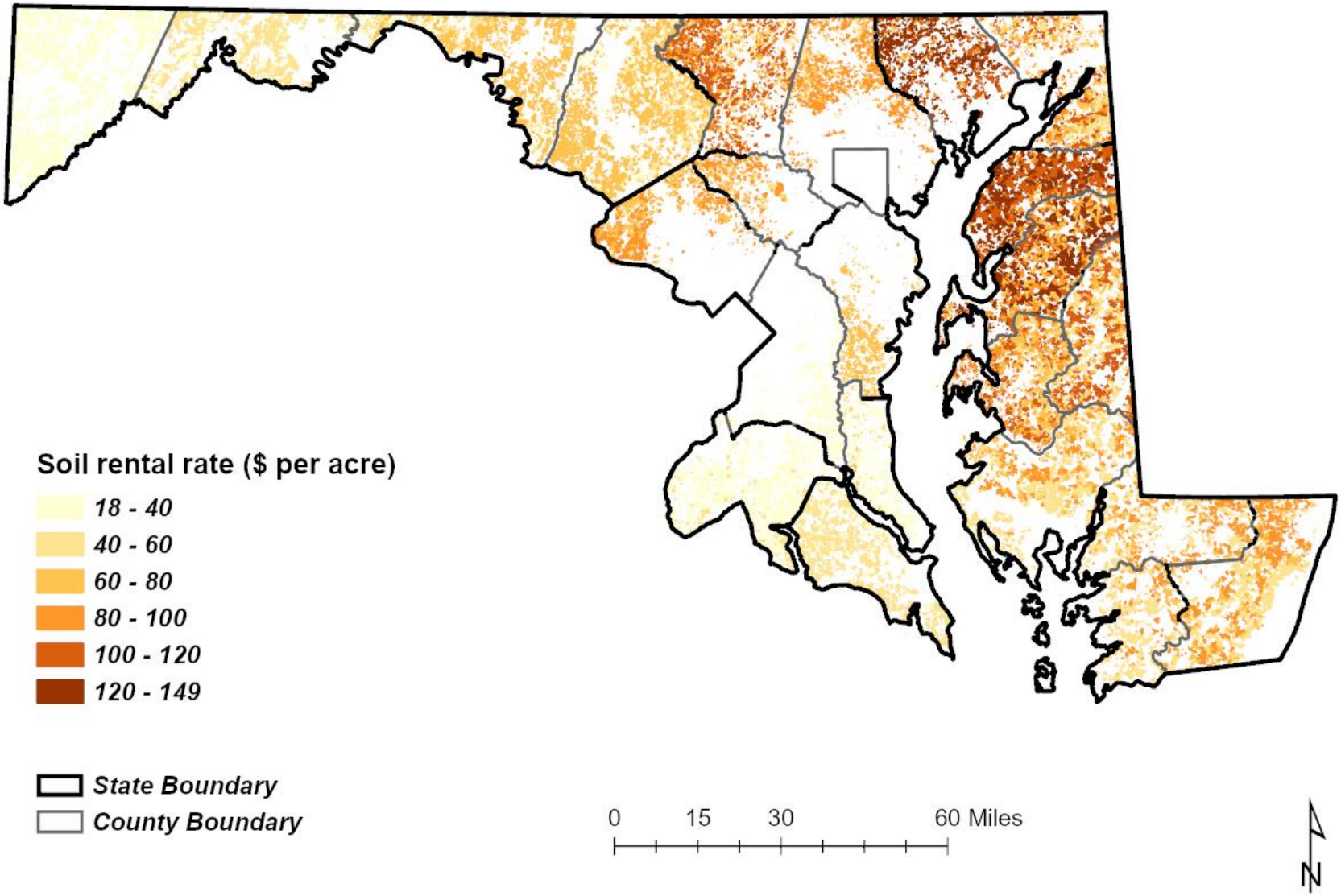
Forest buffer for 15-year contract



CREP (Baseline Scenario)

- **Contract length**
  - Forest buffers: 15 years
  - Grass buffers: 10 years
- **Annual recurring payments based on soil rental rate**
  - Forest buffers = 3*soil rental rate
  - Grass buffers = 2.5*soil rental rate
- **Installation costs fully paid (100% cost-share)**
  - Forest buffer (avg.) = $2,185/acre
  - Grass buffer (avg.) = $330/acre
    - Average installation costs from UMCES report (Price, Flemming, & Wainger 2019)
- **Upfront signing bonus**
  - Forest buffers = $1000/acre
  - Grass buffers = $200/acre

Parcel-level Soil Rental Rate



Policy Scenarios

Policy Scenario	Summary Description

Baseline CREP	• Full (100%) cost-share for buffer installation
	• Signing bonus upfront = $1,000/acre (forest); $200/acre (grass)
	• Annual rental payment based on parcel soil rental rate (SRR)
	  o Forest buffer: 3*SRR for 15-year contract
	  o Grass buffer: 2.5*SRR for 10-year contract for grass

All payments upfront	• Same as Baseline CREP, except convert present value of annual rental payment into a single upfront payment

Shorter contract lengths	• Same as Baseline CREP, except shorter contract length
	  o Forest buffer: 10-year contract
	  o Grass buffer: 5-year contract

Targeted bonus payments	• Same as Baseline CREP, except change signing bonus from uniform $1,000/acre to a targeted payment that varies spatially by the site-specific N reductions achievable on each parcel
Baseline CREP, plus carbon offset payments	• Same as Baseline CREP, plus additional payments for carbon sequestration storage over contract length (forest buffers only)

Policy Scenarios
Forest Buffer (Baseline: 15-year contract)

	Baseline CREP	All payments upfront	Shorter contract lengths	Targeted bonus payments	CREP + carbon payment
Participation rate					
% of landowners	16.4%	27.9%	17.3%	17.3%	17.5%
Total benefits and costs ($ in millions)					
Total benefits	2.36	4.04	1.71	2.60	2.53
Total costs	1.23	2.15	1.12	1.32	1.36
Net benefits	1.13	1.89	0.58	1.28	1.17
Benefit/cost ratio	1.91	1.88	1.52	1.96	1.86
Benefit decomposition (% of total benefits)					
N benefits	84%	85%	85%	85%	84%
P benefits	14%	13%	14%	13%	14%
C benefits	2%	2%	1%	2%	2%

CREP vs Carbon trading:
Representative (average) landowner
Forest buffer in 15-year contract

Carbon trading

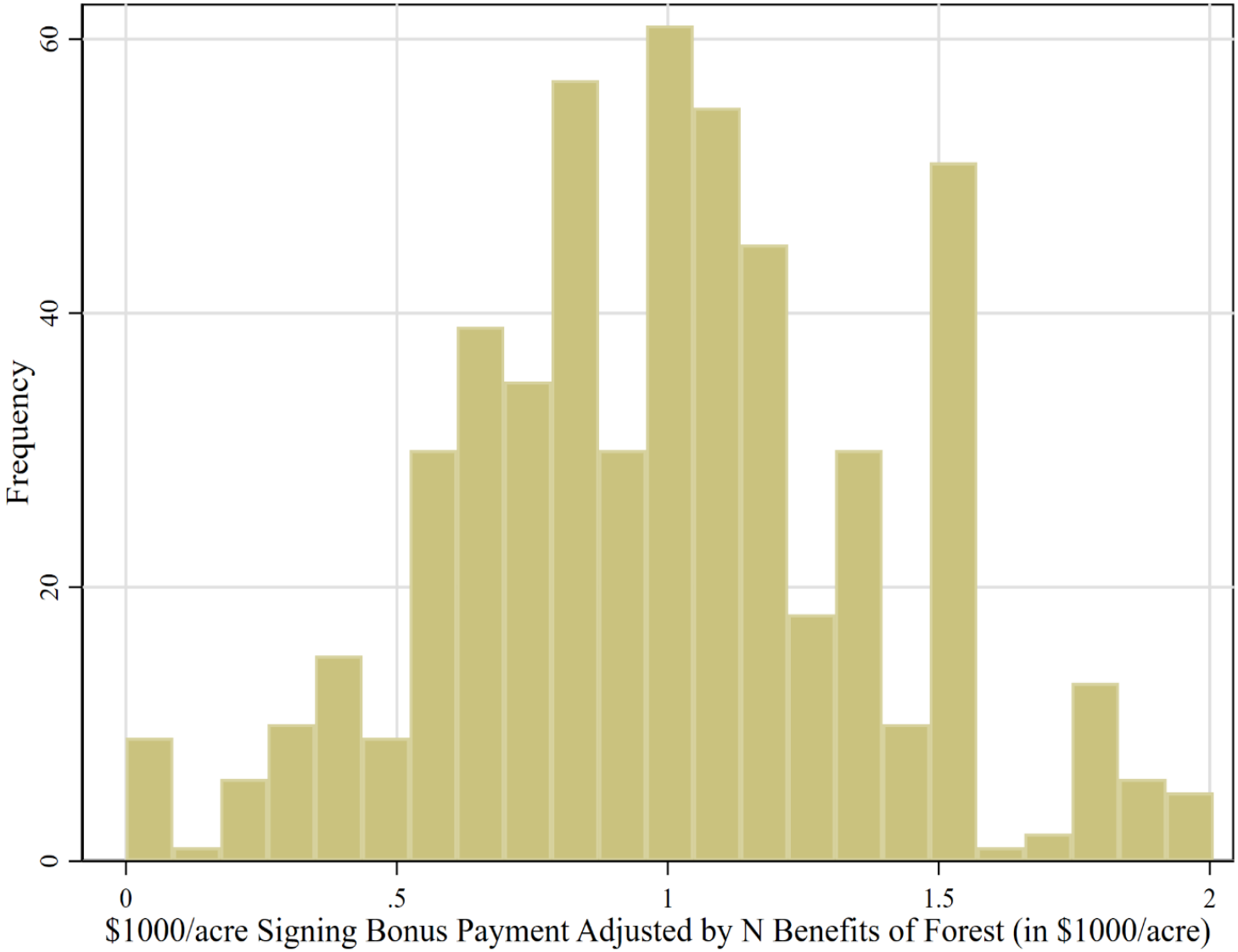
- Regional Greenhouse Gas Initiative (RGGI)
  - RGGI trading price = $35/ton C
- Annual payment (avg.) for carbon sequestration
  - Annual carbon storage in forest buffer (avg.) = 0.38 tons C/acre
  - Annual payment = (0.38 tons C/acre)*($35/ton C) = $13/acre

CREP

- Soil rental rate (avg.) = $77/acre
- CREP annual payment (avg.) = 3*SRR = $231/acre

Payment ($/acre)	**CREP**	**Carbon trading**
Cost-share installation	$2,100	$0
Signing bonus	$1,000	$0
Present value of annual payments for 15 years (discounted at 2.5%)	$2,932	$170
Total payments ($/acre)	$6,032	$170

Targeted signing bonus for forest buffer Scaled by N benefits (average = $1,000/acre)



Conclusions in Summary Report

- **Upfront payments are strongly preferred to annual payments**
  - Increased enrollment
- **Shorter contract periods**
  - Limited effect on enrollment
  - Lower program net benefits
- **Targeted bonus payments**
  - Highest BC ratio
  - All other policy scenarios do not target based on environmental benefits
    - Uniform payments or varying by soil productivity (SRR)
- **Carbon offset payments**
  - CREP is extremely generous, compared to carbon payments

Pay-for-Performance Programs

- **Pilot programs in MD, VA, PA, and Conowingo Susquehanna River Basin**
  - Landowners submit bids for conservation projects (riparian buffers, etc.)

- **Cost-effective ranking to select bids with highest benefit-cost ratio**
  - Benefits: Total nutrient (nitrogen) reductions over contract period
  - Costs: Amount in $ requested by landowner bid over contract period

- **Program design shifts financing to landowner**
  - For approved projects, landowners are responsible for upfront costs to design and install BMPs
  - Government program pays annually for nutrient credits when provided

  - **Advantage**: Creates higher compliance incentive for landowner to maintain the BMP (only gets paid if performing as designed)

  - **Disadvantage**: Small & medium landowners have higher financing costs and risk averse if project fails
    - Challenge to scale from pilot program (large landowners with $1 million projects) to other landowners

Interacting Program Incentives

- **Consider annual cover crops for nitrogen reduction**

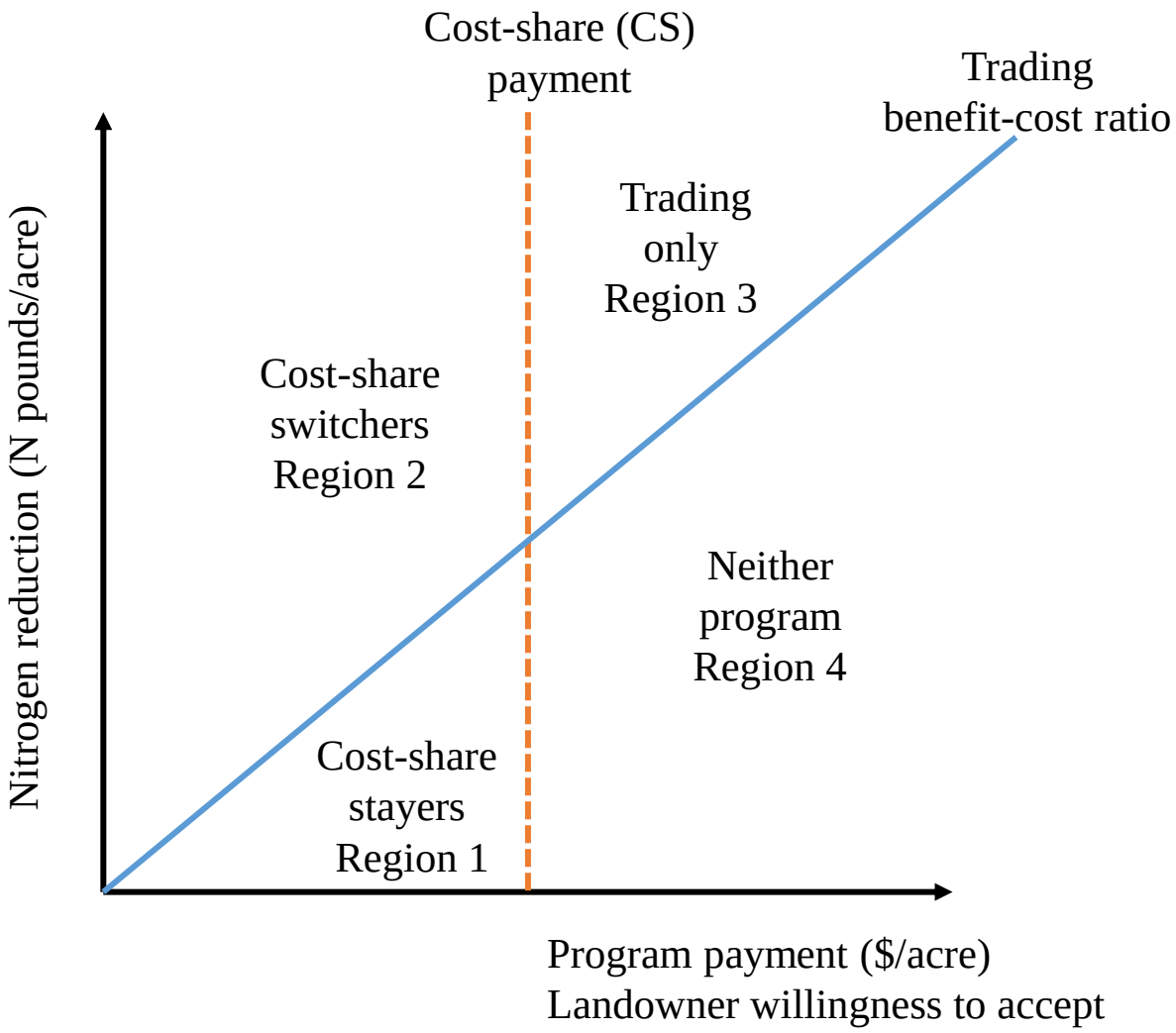
- **Nutrient trading (or Pay-for-performance)**
  - Pays based on cost-benefit ratio ($ per N pound reduction)

- **Agricultural cost-share programs (Pay-for-action)**
  - Maryland Agricultural Water Quality Cost-Share (MACS) Program
  - Pays fixed amount per acre ($65/acre)

Farmer can only choose one program (no double dipping)

Trading or pay-for-performance enters a landscape where existing cost-share programs are dominant and will remain substantial

Interacting Program Incentives



Programs in Isolation

Cost-share alone
Region 1 & 2

Trading alone
Region 2 & 3

Interaction Programs with Competing Incentives

Cost-share
Region 1
(Least efficient landowners stay in cost-share program)

Trading
Region 2 & 3
(Landowners in cost-share switch to trading, but are paid MORE to do the SAME cover crop)

Additional Slides

Next Steps for Outreach

- **Summary report on policy scenarios**
  - Draft report available

- **Engagement**
  - Hold in-person and online meetings with stakeholder groups in fall 2024
    - State and federal agencies
    - Nonprofit organizations
    - University Extension agents

- **Conduct alternative policy options**
  - Alternative program designs based on stakeholder goals (contract length, payment timing, spatial targeting payments, etc.)
  - Willing vs unwilling landowner types for outreach efforts

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Likelihood of Enrollment in Riparian Buffer Program

Factors	Likelihood of Program Enrollment
Program attributes	
Forest buffer (baseline: grass buffer)	0
Upfront payment	+
Annual payment (baseline: 15-year contract)	+ +
Annual payment × 5-year contract	0
Annual payment × 10-year contract	0
Landowner and farm/parcel characteristics	
Crop return	− −
Farm income share	−
Senior	− −
College	0
Rent	+
Risk averse	− −
Conservation subsidy	+ +
Self-funder	+ +
Farm support	−
Opposition to property monitoring	− −
Opposition to tax-funded farm programs	−
Number of observations: 538 landowner parcels (2,111 program choice observations)	

++ Positive relationship at 1% level
+ Positive relationship at 5% level
0 No significant relationship
- - Negative relationship at 1% level
- Negative relationship at 5% level

Policy Scenarios
Grass Buffer (Baseline: 10-year contract)

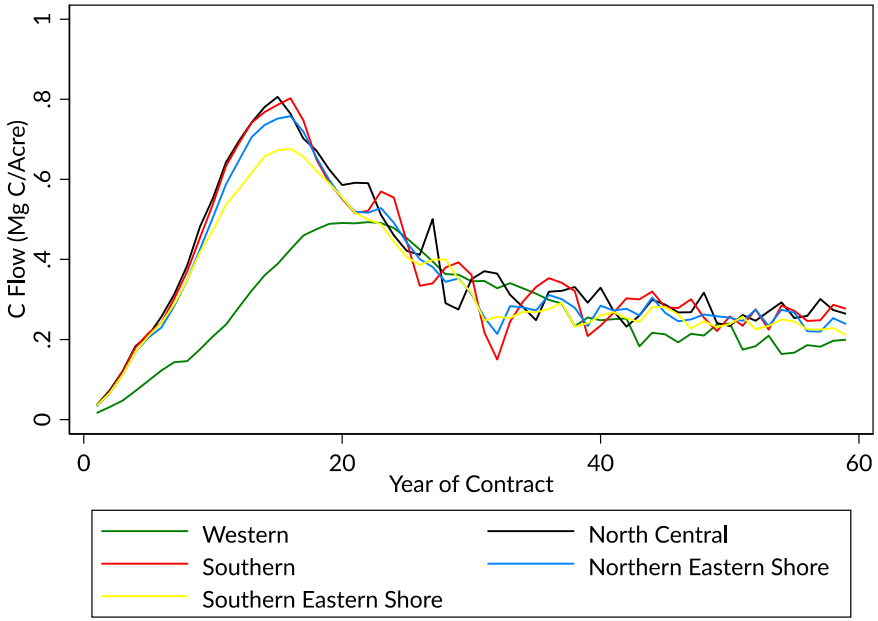
	Baseline CREP	All payments upfront	Shorter contract lengths	Targeted bonus payments
Participation rate				
% of landowners	6.0%	14.6%	4.9%	5.7%
Total benefits and costs ($ in millions)				
Total benefits	0.427	1.037	0.173	0.410
Total costs	0.176	0.437	0.090	0.165
Net benefits	0.252	0.600	0.083	0.245
Benefit/cost ratio	2.43	2.37	1.92	2.48
Benefit decomposition (% of total benefits)				
N benefits	92%	93%	92%	92%
P benefits	8%	7%	8%	8%
C benefits*	NA	NA	NA	NA

Estimated C benefits for grass buffers are not available.

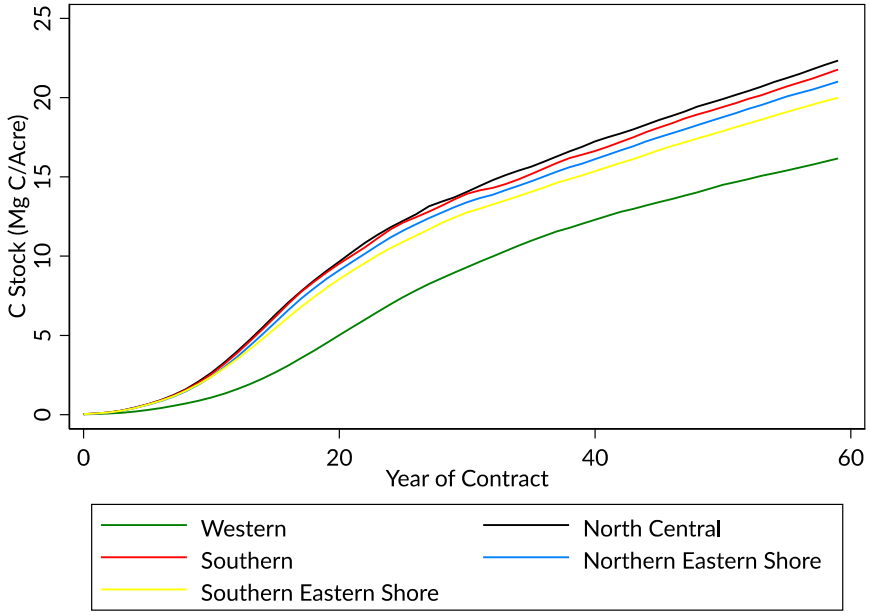
Forest carbon modeling

High-resolution forest carbon modeling for Maryland
(Hurtt et al. 2019; Lamb et al. 2021; Ma et al 2022)

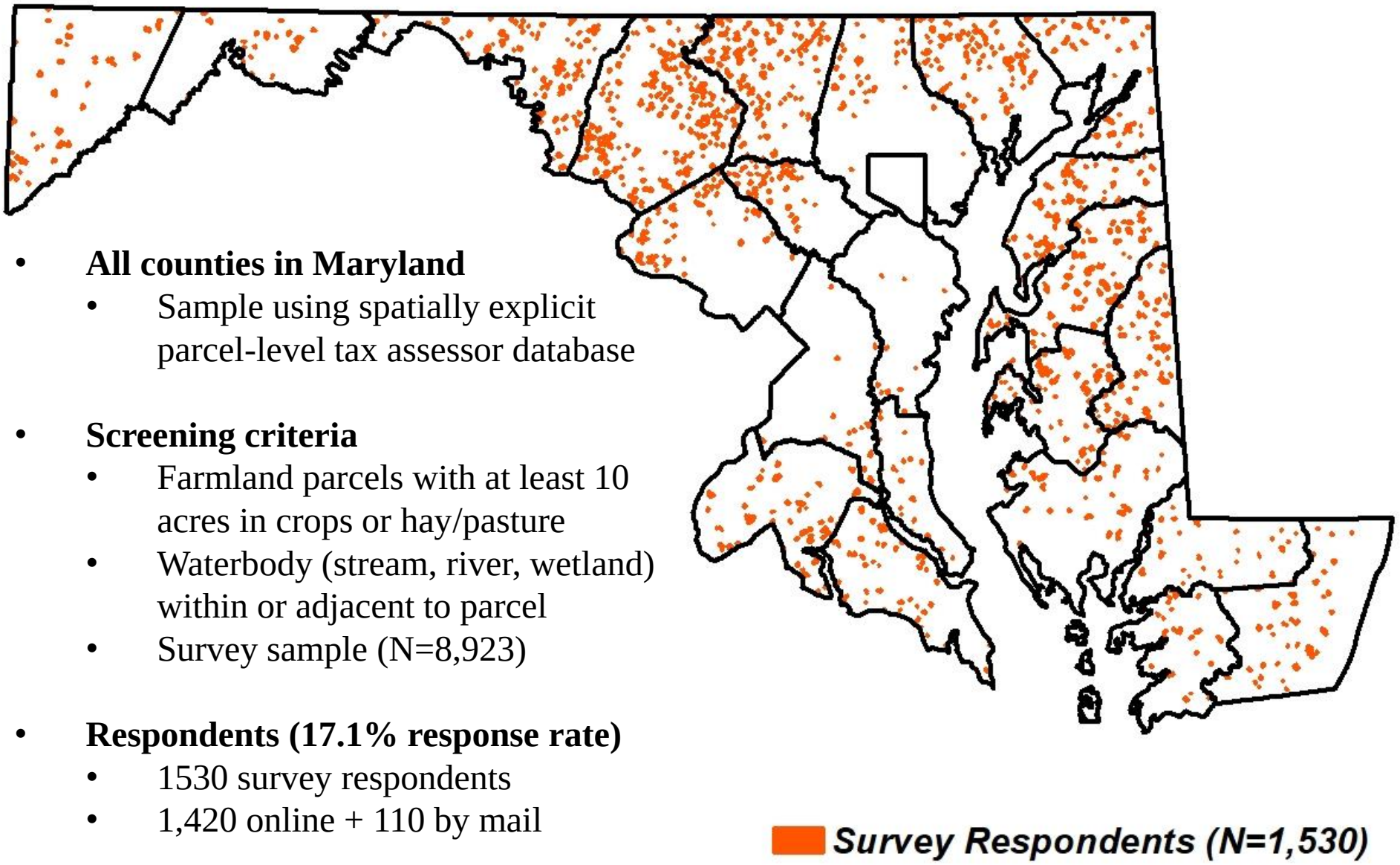
Annual carbon sequestration rate
(metric tons C/acre) by MD region



Total carbon storage over time
(metric tons C/acre) by MD region



Survey Respondents



- **All counties in Maryland**
  - Sample using spatially explicit parcel-level tax assessor database
- **Screening criteria**
  - Farmland parcels with at least 10 acres in crops or hay/pasture
  - Waterbody (stream, river, wetland) within or adjacent to parcel
  - Survey sample (N=8,923)
- **Respondents (17.1% response rate)**
  - 1530 survey respondents
  - 1,420 online + 110 by mail

Riparian Buffer History

	Forest buffers		
	Pre-1998	1998-2009	2009-2021
Enrolled in cost-share program	25	61	37
Self-funded	429	49	38
% buffers enrolled	5.5%	55.5%	49.3%
	Grass buffers		
	Pre-1998	1998-2009	2009-2021
Enrolled in cost-share program	38	54	44
Self-funded	217	70	35
% buffers enrolled	14.9%	43.5%	55.7%
N=1,468 landowners in total			

Hurdle Models

- **Unwilling landowners**
  - Landowner types willing vs. unwilling to enroll
  - 46% of landowners chose not to enroll in any of the 4 randomly assigned proposed programs, despite payments offered higher than current CREP levels

- **First-stage: Probability of unwilling to participate in any program offered**
  - Probit model used to estimate probability that landowner rejects all 4 randomly assigned programs (Not enroll in all 4 programs)

- **Second-stage: Probability of enrollment, conditional on considering participation**
  - Logit model used to estimate probability of enrollment in buffer program as a function of program attributes, landowner characteristics, and farm characteristics (Enroll=1, Not enroll=0)

Landowner and farm/parcel characteristics

Variable	Description	Mean	Min	Max
Crop return	Foregone annual crop income ($/acre)	294	17	744
Farm income	Share of household income from farming	0.15	0	1
Indicator Variables (Yes=1; No =0)				
Senior	Age over 65	0.56	0	1
College	Has a college degree or higher	0.61	0	1
Rent	Rents out some or all farmland within the parcel	0.50	0	1
Risk averse	Is risk averse	0.27	0	1
Conservation subsidy	Received payments for buffers already existing on parcel	0.06	0	1
Self-funder	Landowner self-funded buffers already existing on parcel	0.28	0	1
Farm support	Participates in any farm support programs: crop/revenue insurance, livestock insurance, Farm Service Agency loans, price support programs (commodity loans, loan deficiency payments, etc.)	0.23	0	1
Opposition to property monitoring	Agrees with statement: “The government should not be allowed to come onto my property and monitor my farmland operations”	0.61	0	1
Opposition to tax-funded farm programs	Agrees with statement: “Tax revenues should not be used for farm support programs”	0.19	0	1
Number of observations: 538 landowner parcels				

Logit Econometric Model

Choice equation	Logit	
	Coefficient	S.E.
Program variables		
Forest (yes=1)	-0.129	(0.100)
Signing bonus ($1000/acre)	0.264*	(0.126)
Annual payment ($1000/acre)	0.773**	(0.275)
Annual payment × 10-year contract	0.307	(0.255)
Annual payment × 15-year contract	0.125	(0.262)
Landowner and parcel characteristics		
Rented out (yes=1)	0.254*	(0.102)
% income from farming	-0.685**	(0.202)
Senior (yes=1)	-0.670**	(0.100)
College degree (yes=1)	0.141	(0.106)
Risk averse (yes=1)	-0.761**	(0.118)
Current program enrollee (yes=1)	0.716**	(0.207)
Current self-funder (yes=1)	0.759**	(0.113)
Soil rental rate ($1000/acre)	-3.602**	(1.143)
No government monitoring (yes=1)	-0.676**	(0.102)
No farm support programs (yes=1)	-0.329*	(0.133)
Constant	-0.230	(0.199)

** 1% level
* 5% level

Related Project:
Payments and Penalties

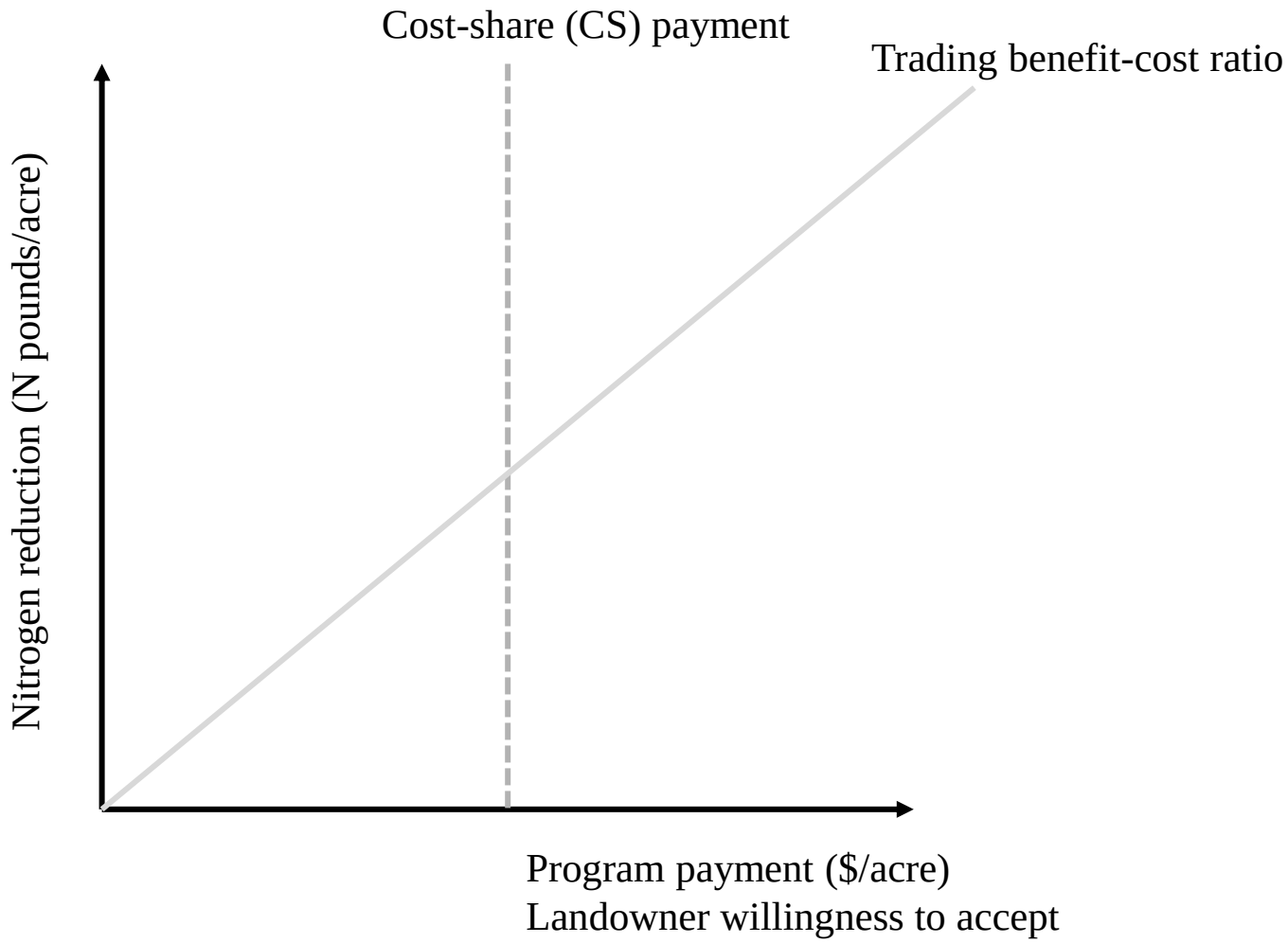
- **Standard penalty for early contract termination**
  - Landowner must pay back all money received, plus interest
  - Exists for all USDA Conservation Programs (CRP, CREP, EQIP)

- **Standard penalty is directly tied to payments**
  - Increased payments lead to higher enrollment
  - But also, indirectly leads to higher penalties that inhibit enrollment

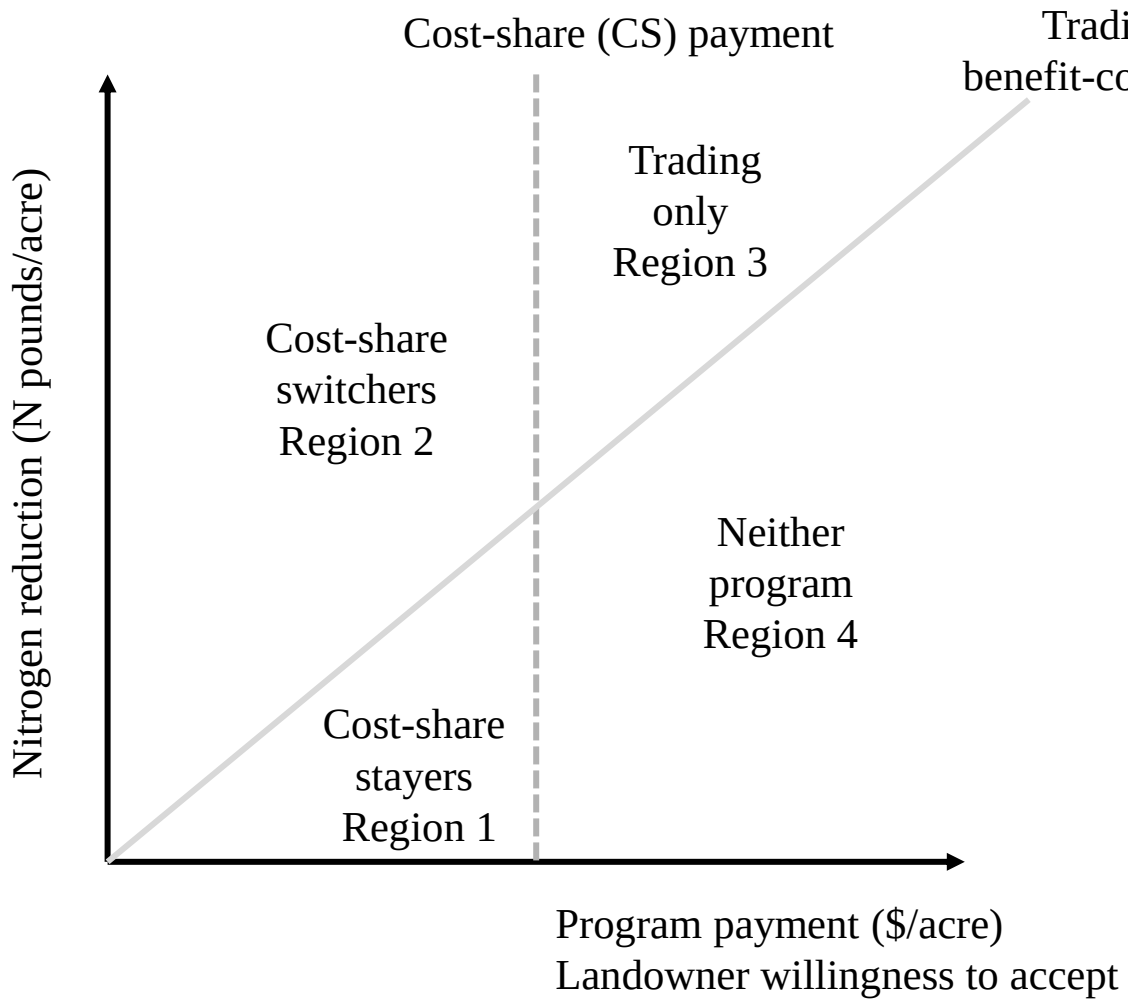
- **Forest buffers are more challenging than grass buffers**
  - Forest buffers have higher payments → higher penalties
  - Higher physical costs for forest buffer removal

- **Optimal penalty**
  - Based on environmental benefits for remaining contract years (forward looking)
  - Not based on payments already received (backward looking)

Interacting Program Incentives



Interacting Program Incentives



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