

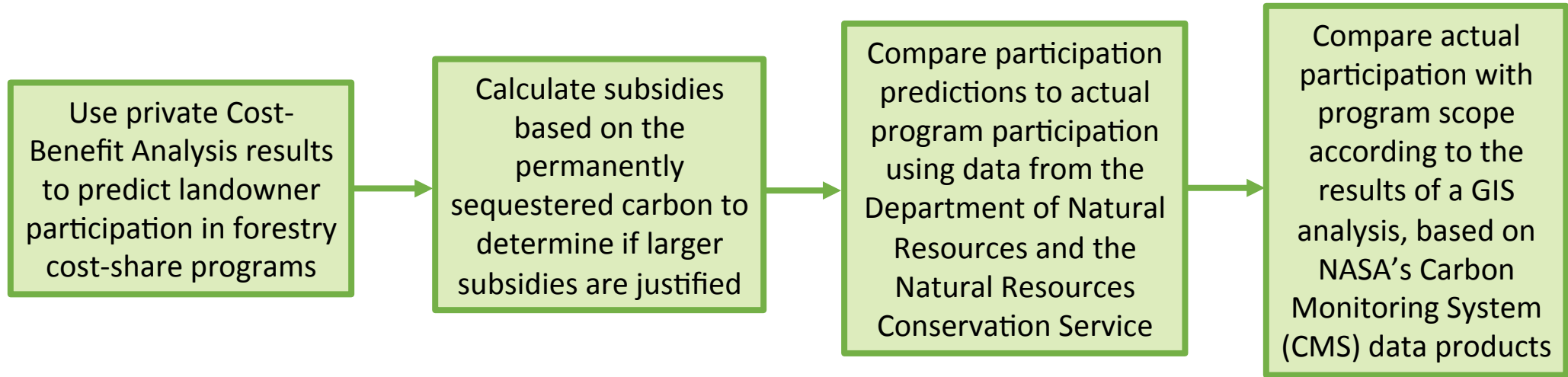
Subsidizing Carbon Sequestration via Forestry in Maryland: A Cost-Benefit Assessment

RACHEL HETTICH

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Motivation

- Increasing GHG emissions and their impact on climate change have emerged as key political and economic topics around the world
- Maintain existing forests + establish new forests = increase carbon sequestration
- Forestry cost-share programs provide subsidies for forestry investments
- Research Questions:
 - Are the current subsidies big enough to elicit program participation? Do net present values (NPVs) of forestry investments turn positive with current subsidies?
 - If the subsidies were based on the amount of permanently sequestered carbon from forestry investments, would they be larger? How do carbon abatement costs of forestry investments compare to current carbon market prices?



Research Organization

Climate Change Initiatives in Maryland

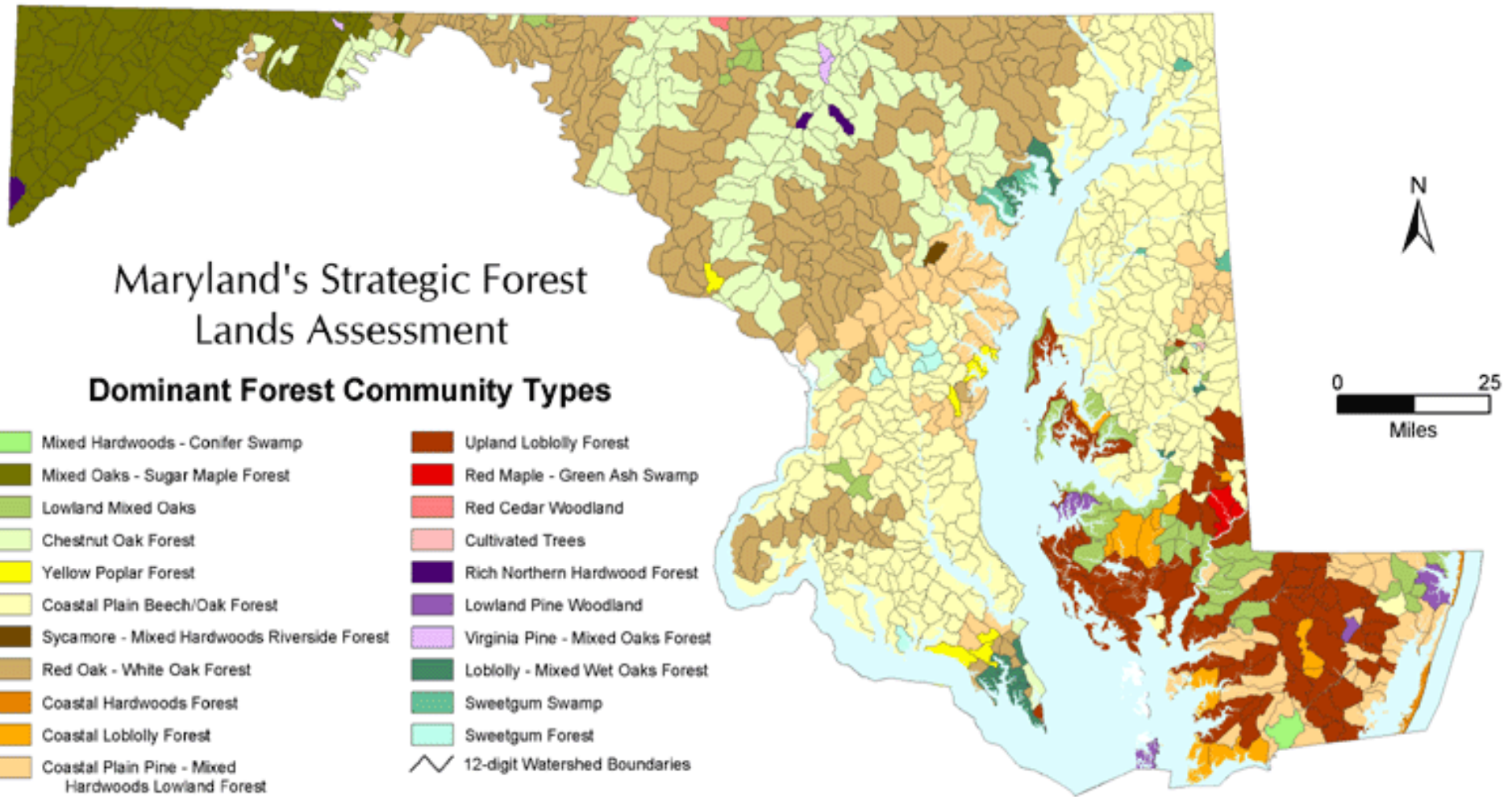
Research Context

- Maryland's Greenhouse Gas Reduction Act Plan (**GHGRP**) passed in 2012
- Reduce GHG emissions by 25% by 2020 (base year 2006)
 - Connecticut has a reduction goal of 10% by 2020 (base year 1990)
- 8.2% of the reductions are projected to come from forestry and sequestration efforts
 - 4.56 million metric tons
- To reach the 8.2% goal, the GHGRP cites federal and state forestry cost-share programs that are in place for private landowners in Maryland

Forestry Cost-Share Programs in Maryland

Research Context

- Environmental Quality Incentives Program (**EQIP**)
 - Federal program that provides cost-share assistance for conservation practices that reduce pollution and improve the state of natural resources
 - Increasing biological carbon storage and sequestration is one of the national EQIP priorities
- Woodland Incentive Program (**WIP**)
 - State program that provides 65% cost-share assistance for timber stand improvements for landowners with at least 5 acres of forested land
- Lawn to Woodland Initiative (**L2W**)
 - New state afforestation program targeting landowners with at least one acre of lawn



Tree Species in Maryland

GIS Analysis

- Data layers used:
 - NASA Carbon Monitoring System (Dubayah et al., 2013):
 - *Canopy Cover*
 - *Carbon Sequestration Potential (CSP)*
 - National Land Cover Database (Jin et al., 2013):
 - *Land Cover Classifications*
 - Maryland Protected Lands Map Server (Maryland iMap, 2014):
 - *DNR Owned Properties*
 - *Rural Legacy Properties*
 - *Permanent Easements*
 - *Other Protected Lands*

Eligible Cell Criteria:

- Conservation Layers = '0' (not conserved)
- Canopy Cover = $\geq 95\%$

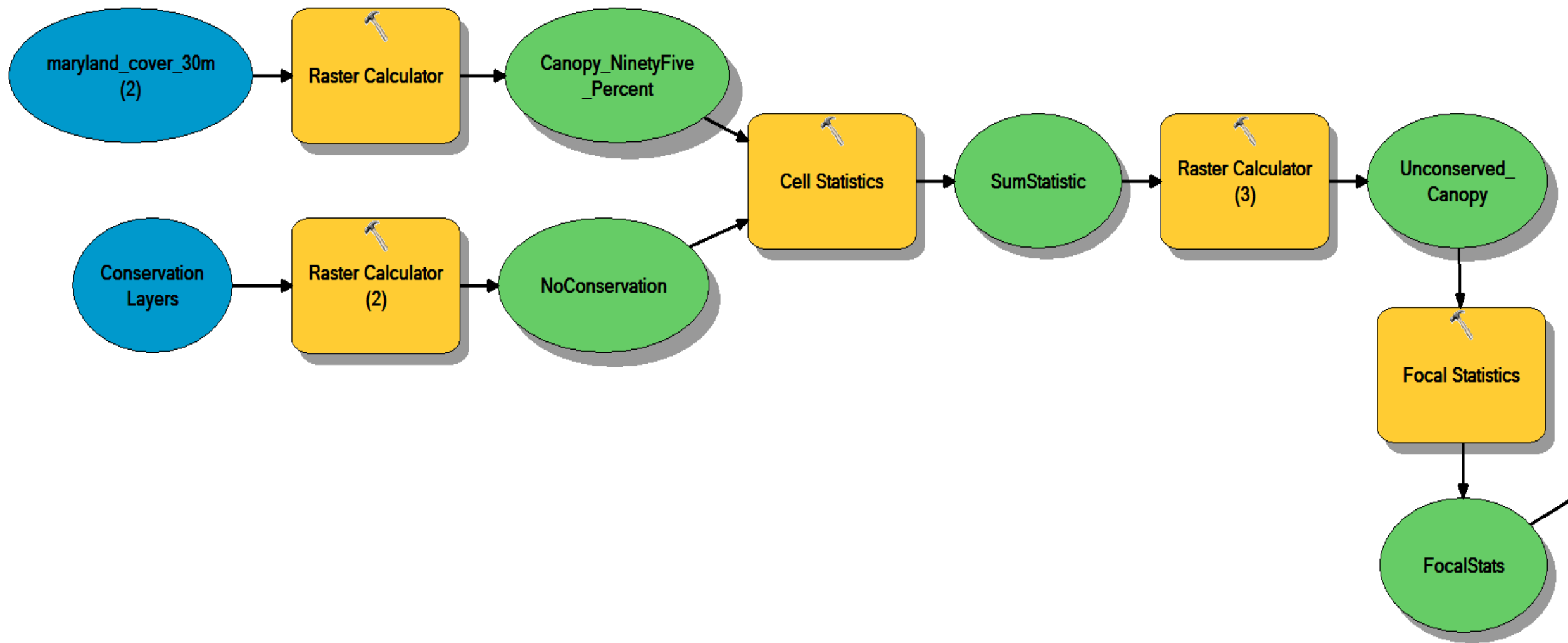


Select Patches of Eligible Cells:

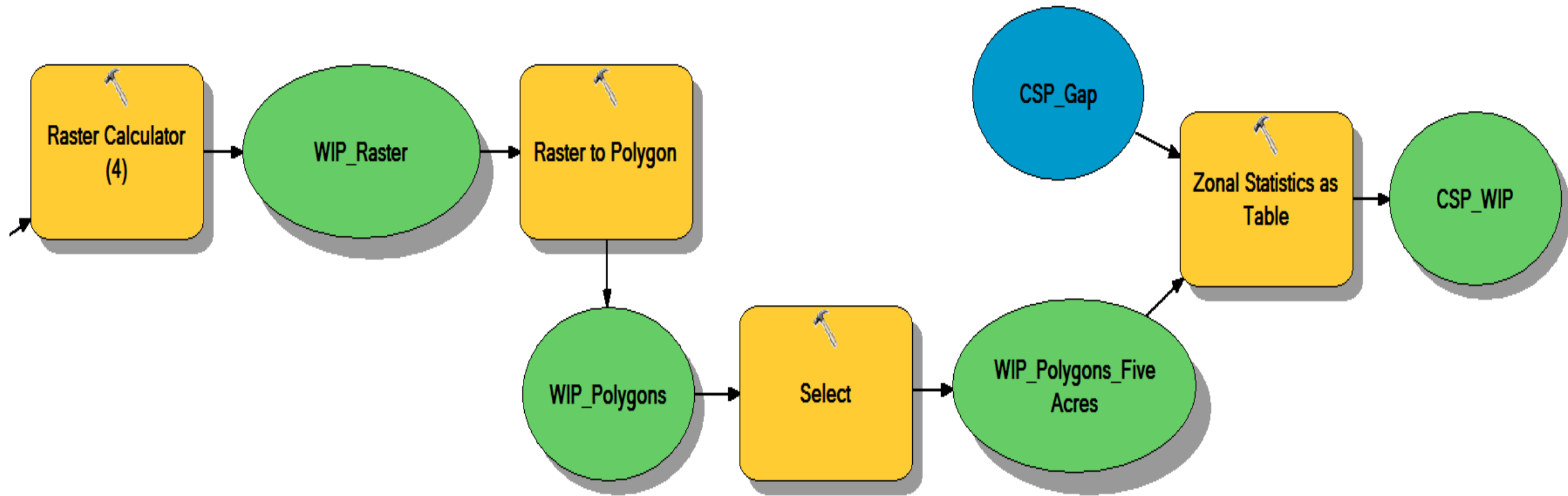
- Any eligible cell that was surrounded on all sides by eligible cells was selected
- Each patch of eligible cells was converted to a polygon
- All polygons ≥ 5 acres were selected



Example Results



WIP Model Builder



WIP Model Builder

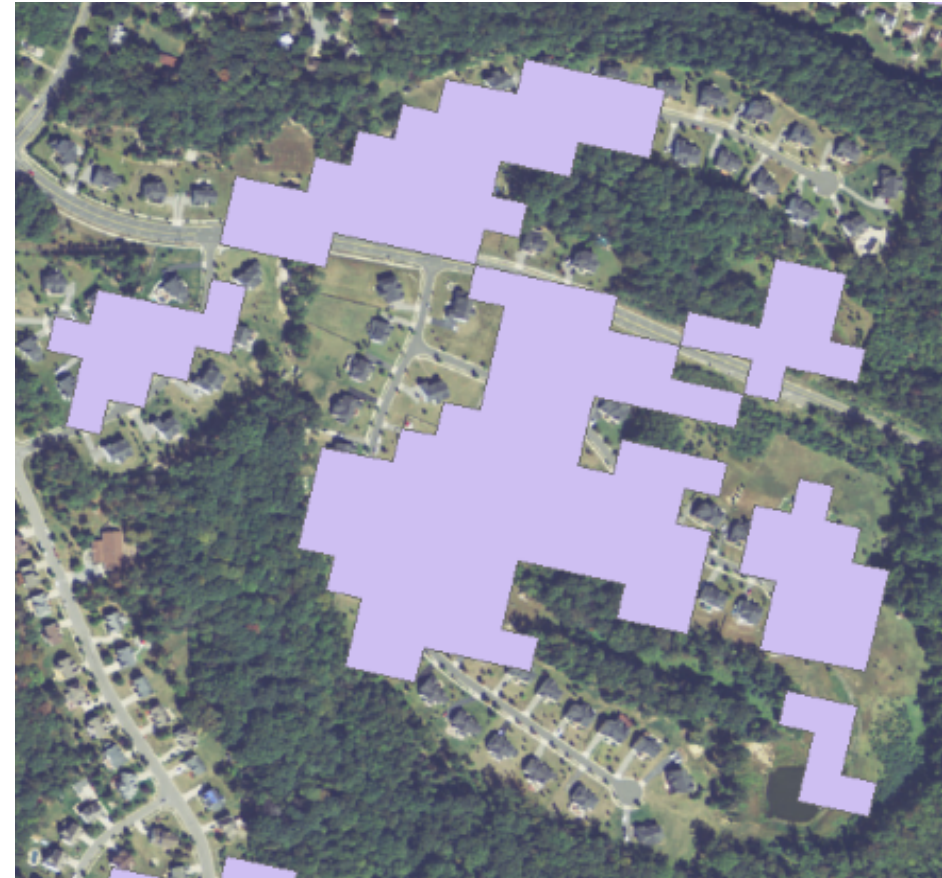
Eligible Cell Criteria:

- Conservation Layers = '0' (not conserved)
- Canopy Cover = $\leq 30\%$
- NLCD = '21' (Developed, Open Space)



Select Patches of Eligible Cells:

- Any eligible cell that was adjacent to at least 3 other eligible cells was selected
- Each patch of eligible cells was converted to a polygon
- All polygons ≥ 1 acre were selected



Example Results

L2W GIS Sensitivity Analysis



CANOPY COVER = 0%
76,659 ELIGIBLE ACRES



CANOPY COVER = 50%
328,016 ELIGIBLE ACRES

- 30% canopy cover was used in the base GIS analysis: 230,450 eligible acres
- Interval calculation: 267,294 eligible acres

Forestry Investment	Scenario Overview
Improving Timber Management	<ul style="list-style-type: none"> ○ Loblolly pine stand ○ Pre-commercially thin at age 4 ○ Participate in WIP: 65% of thinning costs covered ○ Sell timber as softwood pulpwood
Agricultural Land to Forest Conversion	<ul style="list-style-type: none"> ○ Oak/hickory stand establishment ○ Participate in EQIP: cost reimbursement based on EQIP payment rates ○ Sell timber as hardwood sawtimber
Lawn to Forest Conversion	<ul style="list-style-type: none"> ○ Oak/hickory stand establishment ○ Participate in L2W: 100% of establishment costs covered ○ With and without timber harvest ○ Sell timber as hardwood sawtimber

Cost-Benefit Analysis Applied to Forestry Investments

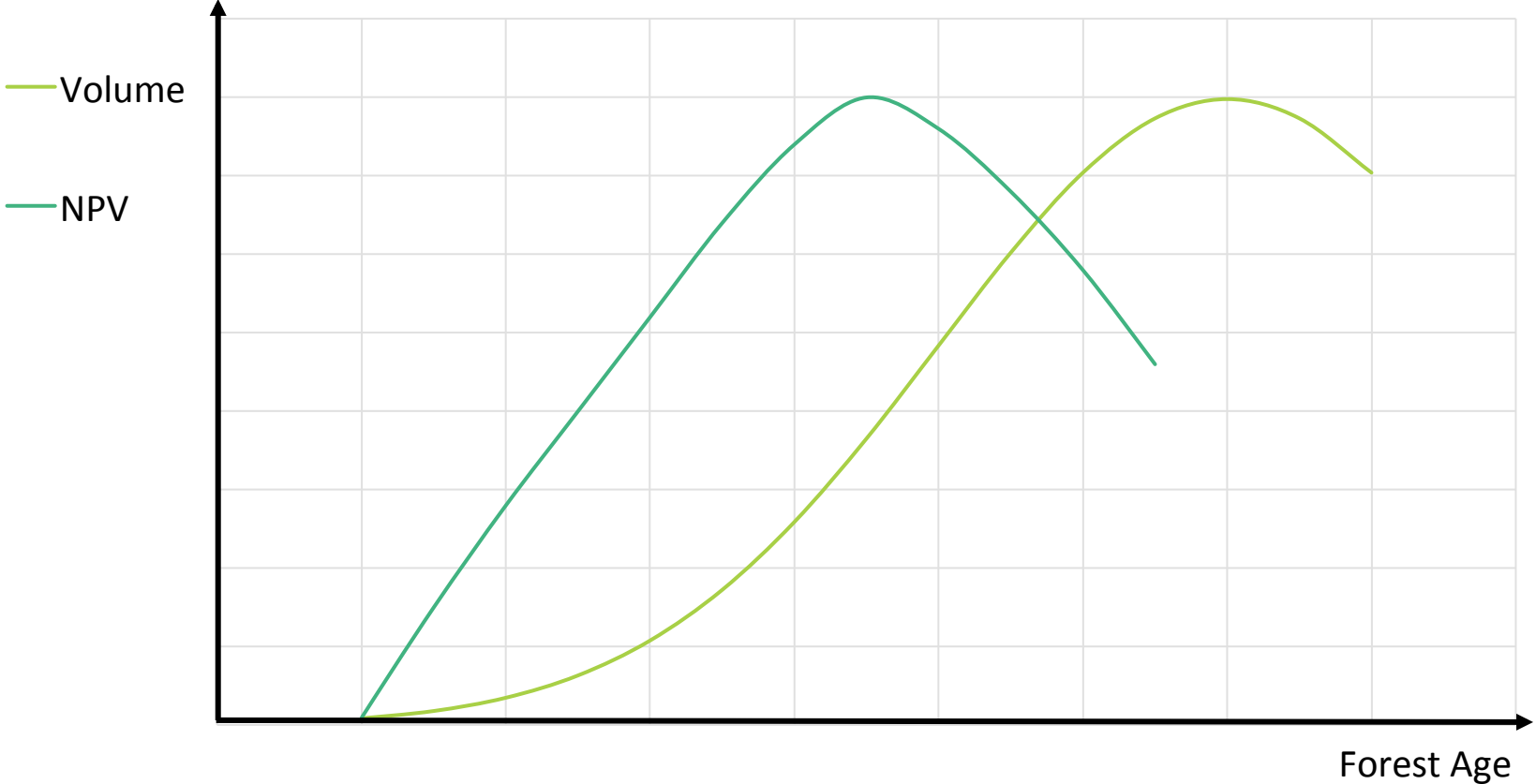
WITH AND WITHOUT ANALYSIS

- Private landowners make land use decisions based on the NPV of land use options (Nelson & Hellerstein, 1997)
- The 'with' case assumes the forestry investment is made
 - 2 cases: one without cost-share assistance and one with cost-share assistance
- The opportunity cost of land use alternatives is quantified in the 'without' case (Campbell & Brown, 2003)
- If 'with' – 'without' is positive, the investment should be made

DISCOUNTING

- The further the benefits and costs occur in the future, the lower their present value today
- Forestry investments: Large up-front costs and no benefits until harvest
- Social cost of carbon estimates are calculated using 3 discount rates: 2.5%, 3%, and 5% (Interagency Working Group, 2013 & Greenstone et al., 2013)

Biologic versus Economic Harvest



Optimal Harvest Year
Biological versus Economic

Data Sources

- *Regional Cost Information for Private Timberland Conversion Management* (Bair & Alig, 2006)
 - USDA Forest Service Publication
- *Costs and Trend of Southern Forestry Practices 2012* (Dooley & Barlow, 2013)
 - Alabama Cooperative Extension System
 - Survey conducted every 2 years, most recent results are from 2012
 - Maryland is the northernmost state included in the survey area
- *An Analysis of the Timber Situation in the United States: 1952-2050* (Haynes, 2003)
 - USDA Forest Service Publication
 - Projects timber demand, supply, and prices

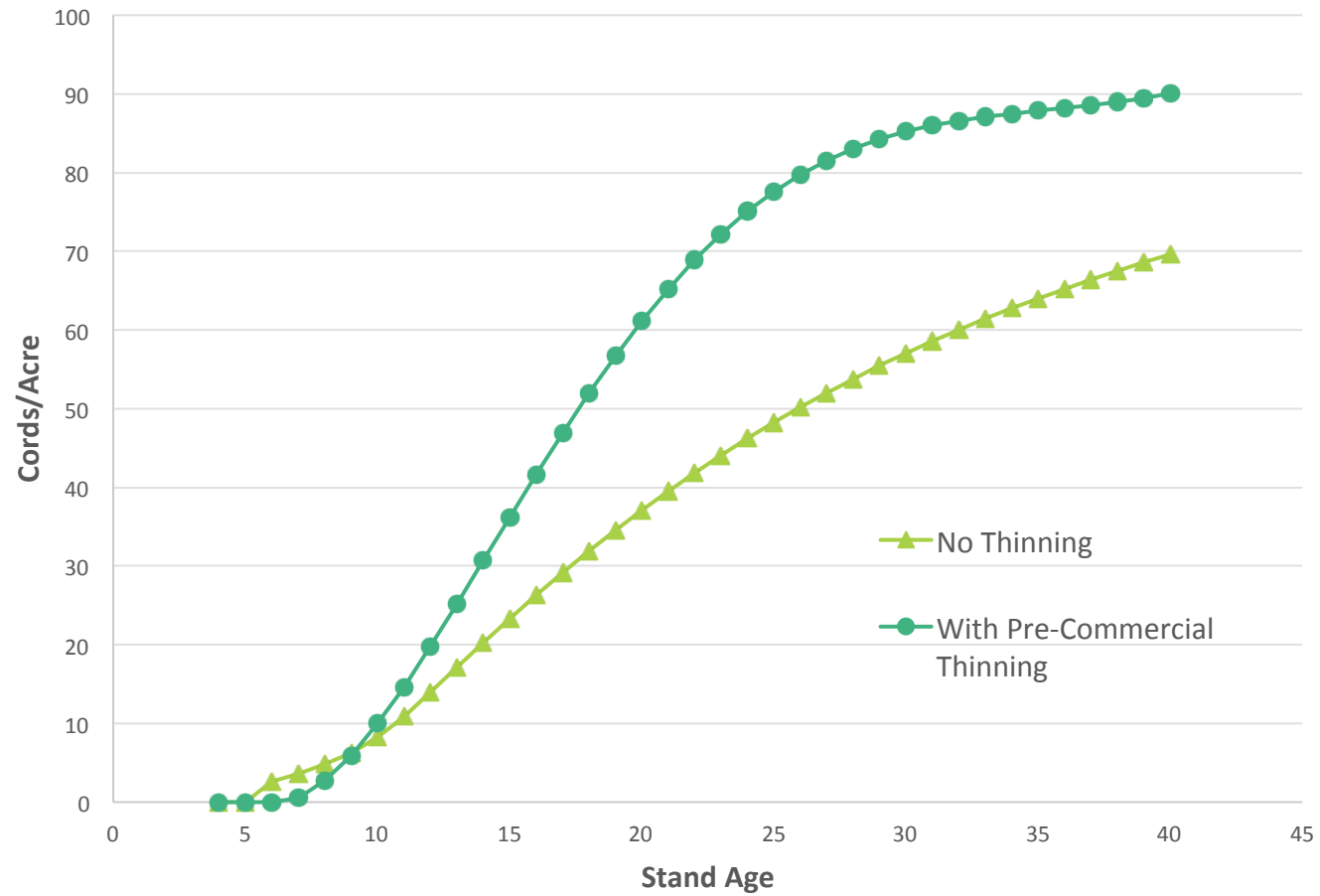
Improving Timber Management

Woodland Incentive Program (WIP)

COST-BENEFIT IMPLEMENTATION AND RESULTS

Pre-Commercial Thinning

- Loblolly pine stands produce seeds at a very high rate, which leads to overstocked stands (Williams et al., 2011)
- Pre-commercial thinning (PCT) removes inferior trees, which leaves the remaining trees with more resources
- Allows the remaining trees to grow faster and larger
- PCT of loblolly pine stands is recommended in the first 3-4 years of growth
- Only cost in this scenario



Loblolly Pine Growth

With and Without Pre-Commercial Thinning

Benefits

- Timber Revenue
 - Without PCT: Harvest at age 25
 - With PCT: Harvest at age 22
 - Sell as softwood pulpwood
- WIP Cost-Share Assistance
 - 65% of PCT cost
- Carbon Sequestration
 - California Cap-and-Trade Program forestry offset protocol
 - *Definition of permanently sequestered carbon:* Carbon that remains sequestered in in-use wood products or in landfills for at least 100 years
 - 9% for softwood pulpwood (California offset protocol, Smith et al., 2006)
 - *Monetize the permanently sequestered carbon:* Used government social cost of carbon (SCC) estimates and the California carbon price

Private Analysis Results

No Carbon Benefits

Base Case NPVs (\$/acre)

Discount Rate	Without PCT	With PCT	With PCT & WIP
2.5%	\$265.25	\$282.74	\$364.09
3%	\$239.49	\$248.54	\$329.88
5%	\$159.91	\$139.20	\$220.54

With minus Without (\$/acre)

Discount Rate	With PCT	With PCT & WIP
2.5%	\$17.49	\$98.93
3%	\$9.05	\$90.39
5%	-\$20.72	\$60.62

Social Analysis Results

Carbon Benefits Included

With minus Without: Including Carbon Benefits (\$/acre)

Discount Rate	Inclusion of Carbon Benefits	With PCT	With PCT & WIP
2.5%	SCC	\$164.31	\$245.65
	Carbon Price	\$46.73	\$128.08
3%	SCC	\$99.49	\$180.83
	Carbon Price	\$36.80	\$118.15
5%	SCC	\$1.22	\$82.57
	Carbon Price	\$1.93	\$83.27

Cost-Share Assistance Comparison (\$/acre)

Discount Rate	Current WIP Cost-Share	Cost-Share Based on California Price	Cost-Share Based on SCC Estimates
2.5%	\$81.34	\$29.25	\$146.82
3%	\$81.34	\$27.75	\$90.44
5%	\$81.34	\$22.65	\$21.94

Social Cost of Carbon Estimates: 2.5%: \$60.96, 3%: \$39.57, 5%: \$11.76

California Carbon Price: \$12.14 (mid-March)

Conclusions

- Improving Timber Management
 - CBA predicts the private landowner will invest in pre-commercial thinning with cost-share assistance from WIP
 - From society's perspective, cost-share assistance based on the carbon benefits would almost double the subsidies
 - Actual enrollment 2007-2014: 24,443 acres
 - Eligible land in Maryland: 736,761 acres
 - CSP on eligible acres: 138.82 million tons

Agricultural Land to Forest Conversion

Environmental Quality Incentives Program (EQIP)

COST-BENEFIT IMPLEMENTATION AND RESULTS

Costs & Benefits

COSTS

- Establishment Costs
 - Site Preparation
 - Planting
- Management Costs
 - Fertilizer
 - Herbicide
 - Miscellaneous Management

BENEFITS

- Timber Revenue
 - Harvest at age 40
 - Sell as hardwood sawtimber
- EQIP Cost-Share Assistance
 - Based on the 2015 payment rates
 - \$297.51/acre for high density mechanical planting
- Average Cropland or Pastureland Cash Rent
- Carbon Sequestration
 - 31.6% for hardwood sawtimber included permanent (Smith et al., 2006)

Cropland Private Analysis Results

No Carbon Benefits

Base Case NPVs: Using Cropland Rent (\$/acre)

Discount Rate	Without Conversion	With Conversion	With Conversion & EQIP
2.5%	\$2124.08	\$1,048.91	\$1,346.42
3%	\$1962.22	\$775.30	\$1072.81
5%	\$1,477.61	\$101.08	\$398.59

With minus Without: Using Cropland Rent (\$/acre)

Discount Rate	With Conversion	With Conversion & EQIP
2.5%	-\$1,075.07	-\$777.56
3%	-\$1,186.92	-\$889.41
5%	-\$1,376.52	-\$1,079.01

Cropland Social Analysis Results

Carbon Benefits Included

With minus Without: Using Cropland Rent & Including Carbon Benefits (\$/acre)

Discount Rate	Inclusion of Carbon Benefits	With Conversion	With Conversion & EQIP
2.5%	SCC	-\$833.44	-\$535.93
	Carbon Price	-\$1,027.01	-\$729.50
3%	SCC	-\$1,049.04	-\$751.53
	Carbon Price	-\$1,144.67	-\$847.16
5%	SCC	-\$1,351.59	-\$1,054.08
	Carbon Price	-\$1,350.79	-\$1,053.28

Marginal Land Results

With & Without Carbon Benefits

With minus Without: Using Pastureland Rent (\$/acre)

Discount Rate	With Conversion	With Conversion & EQIP
2.5%	\$122.01	\$419.52
3%	-\$81.01	\$216.50
5%	-\$534.74	-\$246.23

With minus Without: Using Pastureland Rent & Including Carbon Benefits (\$/

Discount Rate	Inclusion of Carbon Benefits	With Conversion	With Conversion & EQIP
2.5%	SCC	\$363.74	\$661.25
	Carbon Price	\$170.16	\$467.67
3%	SCC	\$56.96	\$354.47
	Carbon Price	-\$38.67	\$258.84
5%	SCC	-\$518.75	-\$221.23
	Carbon Price	-\$517.94	-\$220.43

Cost-Share Assistance Comparison

Cost-Share Assistance Comparison (\$/acre)

Discount Rate	Current WIP Cost-Share	Cost-Share Based on California Price	Cost-Share Based on SCC Estimates
2.5%	\$297.51	\$48.15	\$241.73
3%	\$297.51	\$42.34	\$137.97
5%	\$297.51	\$25.80	\$25.00

*Social Cost of Carbon Estimates: 2.5%: \$60.96, 3%: \$39.57, 5%: \$11.76
California Carbon Price: \$12.14 (mid-March)*

Conclusions

- Agricultural Land to Forest Conversion
 - CBA predicts the landowner will not convert cropland to forest, even with participation in EQIP and the inclusion of carbon benefits (from private and social perspectives)
 - The conversion from pastureland to forest is much more likely, but the landowner would still choose not to convert at a discount rate of 5%
 - Actual enrollment from 2009-2013: 344 acres
 - Eligible land in Maryland: 1.2 million acres of cropland, 746,903 acres of hay/pastureland
 - CSP on eligible acres: 2547.69 million tons

Lawn to Forest Conversion

Lawn to Woodland (L2W)

COST-BENEFIT IMPLEMENTATION AND RESULTS

Costs & Benefits

COSTS

- Establishment Costs
 - Site Preparation
 - Planting
- Management Costs
 - Fertilizer
 - Herbicide
 - Miscellaneous Management
- Lawn Maintenance Costs (Zhou et al., 2009)
 - Annual average of lawn care services, supplies, equipment repair, equipment rentals, and equipment purchases

BENEFITS

- Timber Revenue
 - Harvest at age 40
 - Sell as hardwood sawtimber
- L2W Cost-Share Assistance
 - 100% of establishment costs
- Carbon Sequestration
 - 31.6% for hardwood sawtimber included permanent (Smith et al., 2006)
 - 100% in cases without timber harvest

Private Analysis Results

No Carbon Benefits

Base Case NPVs (\$/acre)

Discount Rate	No Timber Harvest		With Timber Harvest		
	Without Conv.	With Conv.	With Conv. & L2W	With Conv. & L2W	
2.5%	-\$11,230.18	-\$616.41	-\$280.50	\$1,033.31	\$1,369.22
3%	-\$10,374.88	-\$599.38	-\$263.47	\$758.54	\$1,094.45
5%	-\$7,812.57	-\$548.35	-\$212.44	\$80.86	\$416.77

Social Analysis Results

Carbon Benefits Included

NPVs Including Carbon Benefits from California Price (\$/acre)

	No Timber Harvest		With Timber Harvest	
Discount Rate	With Conv.	With Conv. & L2W	With Conv.	With Conv. & L2W
2.5%	-\$368.23	-\$32.32	\$1,081.46	\$1,417.37
3%	-\$381.16	-\$45.25	\$800.88	\$1,136.79
5%	-\$415.35	-\$79.44	\$106.66	\$442.57

NPVs Including Carbon Benefits from SCC Estimates (\$/acre)

	No Timber Harvest		With Timber Harvest	
Discount Rate	With Conv.	With Conv. & L2W	With Conv.	With Conv. & L2W
2.5%	\$629.47	\$965.38	\$1,275.03	\$1,610.95
3%	\$111.72	\$447.63	\$896.51	\$1,232.42
5%	-\$419.50	-\$83.59	\$105.86	\$441.77

Cost-Share Assistance Comparison

Cost-Share Assistance Comparison Without Harvest (\$/acre)

Discount Rate	Current L2W Cost-Share	Cost-Share Based on California Price	Cost-Share Based on SCC Estimates
2.5%	\$335.91	\$248.18	\$1,245.87
3%	\$335.91	\$218.22	\$711.10
5%	\$335.91	\$133.00	\$128.85

Cost-Share Assistance Comparison With Harvest (\$/acre)

Discount Rate	Current L2W Cost-Share	Cost-Share Based on California Price	Cost-Share Based on SCC Estimates
2.5%	\$335.91	\$48.15	\$241.73
3%	\$335.91	\$42.34	\$137.97
5%	\$335.91	\$25.80	\$25.00

*Social Cost of Carbon Estimates: 2.5%: \$60.96, 3%: \$39.57, 5%: \$11.76
California Carbon Price: \$12.14 (mid-March)*

Conclusions

- Lawn to Forest Conversion
 - CBA predicts the landowner will convert lawn to forest in all cases
 - Aesthetic values become the determining factor
 - From society's perspective, cost-share assistance based on the carbon benefits would almost quadruple the current cost-share (in the case with no timber harvest)
 - Actual enrollment 2014: 15 acres
 - Eligible land in Maryland: 230,450 acres
 - CSP on eligible acres: 301.56 million tons

Summary of Carbon Impacts

CARBON POTENTIAL AND RELATIVE ABATEMENT COSTS

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Carbon Sequestration Potential of Maryland's Forestry Programs

All values are in millions of tons of carbon

	Potential of Enrolled Land	Total Lifetime Potential of all Eligible Land	GHGRP Estimated Potential
WIP	4.61	138.82	
EQIP Conversion of Cropland Conversion of Pastureland	0.45	1570.30 977.39	
L2W	0.02	301.56	
Total Forestry Efforts	5.08	2988.07	4.56

Effective Abatement Costs of Forestry Investments

All values are in 2010 \$/ton of carbon

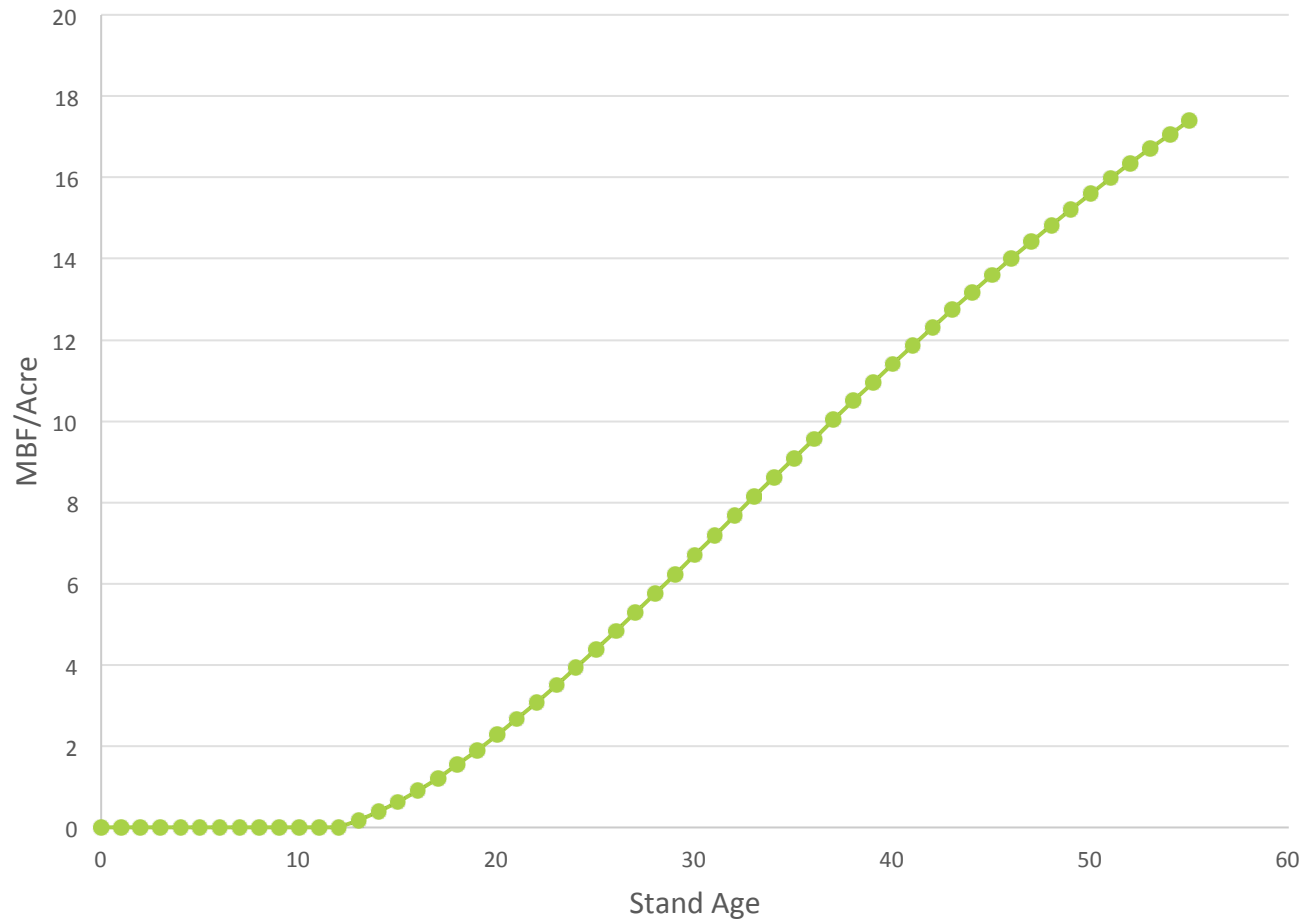
	Discount Rate		
	2.5%	3%	5%
WIP – PCT	-\$12.67	-\$6.56	\$15.02
EQIP – Agricultural Land Conversion			
Conversion of Cropland	\$138.24	\$152.62	\$176.99
Conversion of Pastureland	-\$15.69	\$10.42	\$69.91
L2W – Lawn Conversion			
With Timber Harvest	-\$1,576.76	-\$1,431.47	-\$1,014.89
Without Timber Harvest	-\$102.70	-\$94.59	-\$70.29
Excluding Lawn Maintenance Costs			
With Timber Harvest	-\$132.86	-\$97.53	-\$10.40
Without Timber Harvest	\$5.96	\$5.80	\$5.31
Marginal Abatement Costs – Carbon Prices			
California	\$12.14	\$12.14	\$12.14
RGGI	\$4.94	\$4.94	\$4.94
Marginal Damage – Social Cost of Carbon			
Constant	\$54.54	\$34.22	\$11.76
Rising	\$60.96	\$39.57	\$11.76

Questions?

PCT Sensitivity Analysis

Difference in NPVs using PCT Cost Extremes (\$/acre)

Discount Rate	PCT Cost	Additional NPV from PCT	Additional NPV from PCT & WIP
2.5%	Min	\$107.92	\$130.48
	Max	(\$72.94)	\$67.18
3%	Min	\$99.48	\$122.04
	Max	(\$81.38)	\$58.74
5%	Min	\$69.71	\$92.28
	Max	(\$111.15)	\$28.97



Oak/Hickory Growth

Costs	\$/acre	Inclusion in 'Without' Case	Inclusion in 'With' Cases
Site Preparation	\$114.34	-	Year 0
Planting	\$190.79	-	Year 0
Herbicide	\$82.39	-	Year 1
Fertilizer	\$20.88	-	Years 5, 10, 15, 20, 25, 30, 35, 40
Miscellaneous Management	\$2.35	-	Annually Beginning in Year 1
Forest Property Tax	\$2.16	-	Annually Beginning in Year 0
Cropland Property Tax	\$3.61	Annually Beginning in Year 0	-

Costs	\$/acre	Inclusion in 'Without' Case	Inclusion in 'With' Cases
Site Preparation	\$145.13	-	Year 0
Planting	\$190.79	-	Year 0
Herbicide	\$82.39	-	Year 1
Fertilizer	\$20.88	-	Years 5, 10, 15, 20, 25, 30, 35, 40
Miscellaneous Management	\$2.35	-	Annually Beginning in Year 1
Forest Property Tax	\$1.58	-	Annually Beginning in Year 0
Cropland Property Tax	\$2.64	Annually Beginning in Year 0	-
Lawn Care Costs	\$427.59	Annually Beginning in Year 0	-

L2W Model Builder

