Land Change Forecasts and Vulnerability Assessments

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U.S. Department of the Interior
U.S. Geological Survey

Acknowledgements

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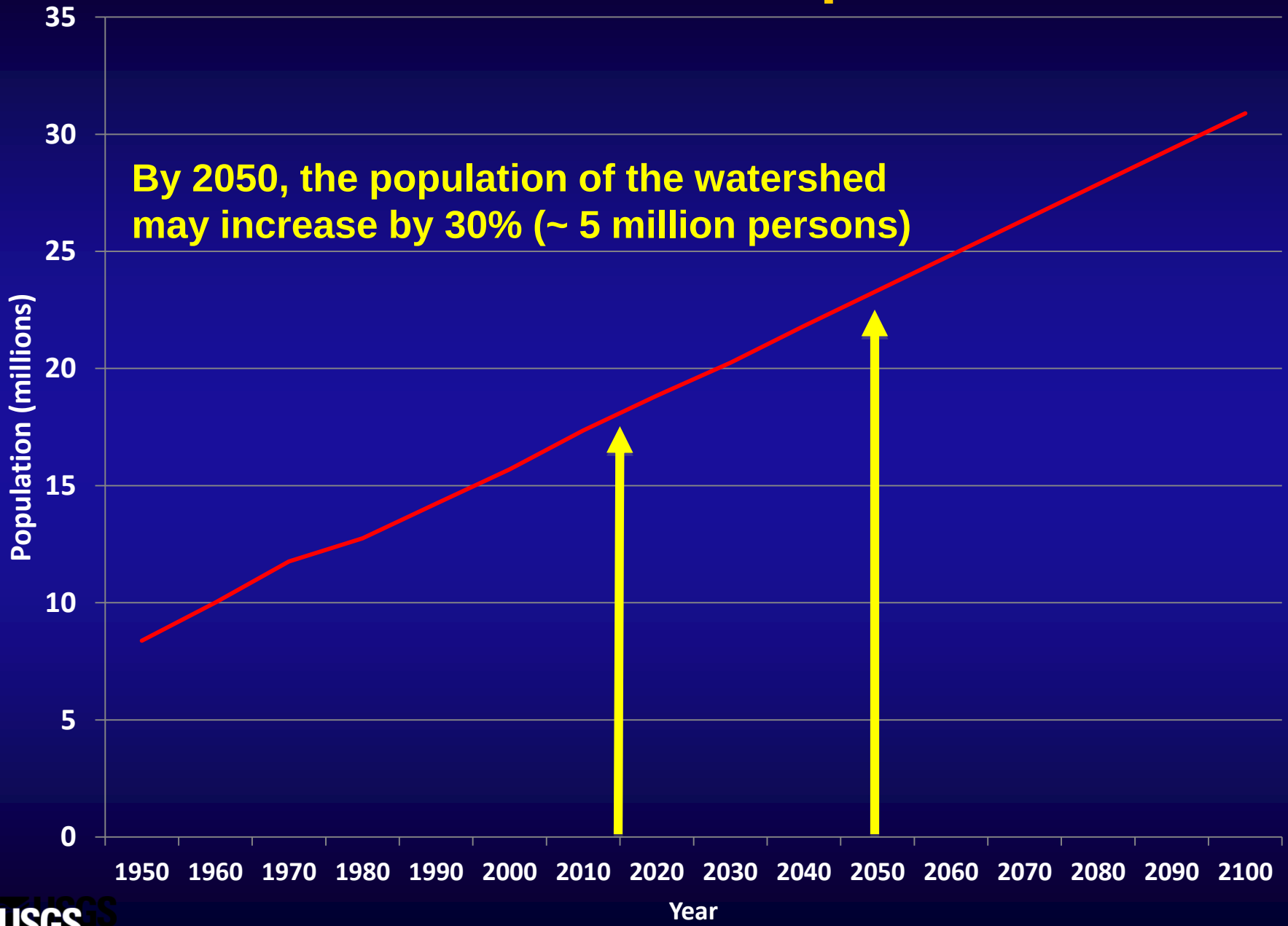
Collaborators include the University of Maryland National Center for Smart Growth Education and Research, American Farmland Trust, and the Planning Departments of Talbot and Howard Counties, Maryland.

Presentation Outline

1. Why forecast future growth?
2. How we do it?
3. Role and importance of scenarios.
4. Results and model assumptions.
5. Assessing “vulnerability”.

Future Watershed Population



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The Bay TMDL

1. Implementation of actions to restore the Bay are planned to take 10 more years (2015 – 2025).

2. Ecosystem responses to those actions may take decades due to groundwater lag times and other factors.

3. By 2050, the population of the watershed may increase by 30% (~ 5 million persons); and

4. EPA expects that ALL new or increased loadings of nitrogen, phosphorous and sediments will be offset by reductions and credits generated by other sources.

USGS

2014 Chesapeake Bay Agreement Decisions (select examples)

1. Increase the proportion of “forests” along “streams” [illegible]% to 70% throughout the watershed.

2. Expand “urban tree canopy” by 2,400 [illegible] by 2025.

3. Achieve and sustain 185,000 [illegible] of “Submerged Aquatic Vegetation”.

4. Create or re-establi[illegible],000 acres of “wetlands”.

5. Characterize [illegible]e rate of “impervious surface” change at the local level.

6. Assess vulnerabilities to “healthy watersheds”.

REQUIRES MEASURES OF NET CHANGE

REQUIRES MODELING FUTURE CHANGE

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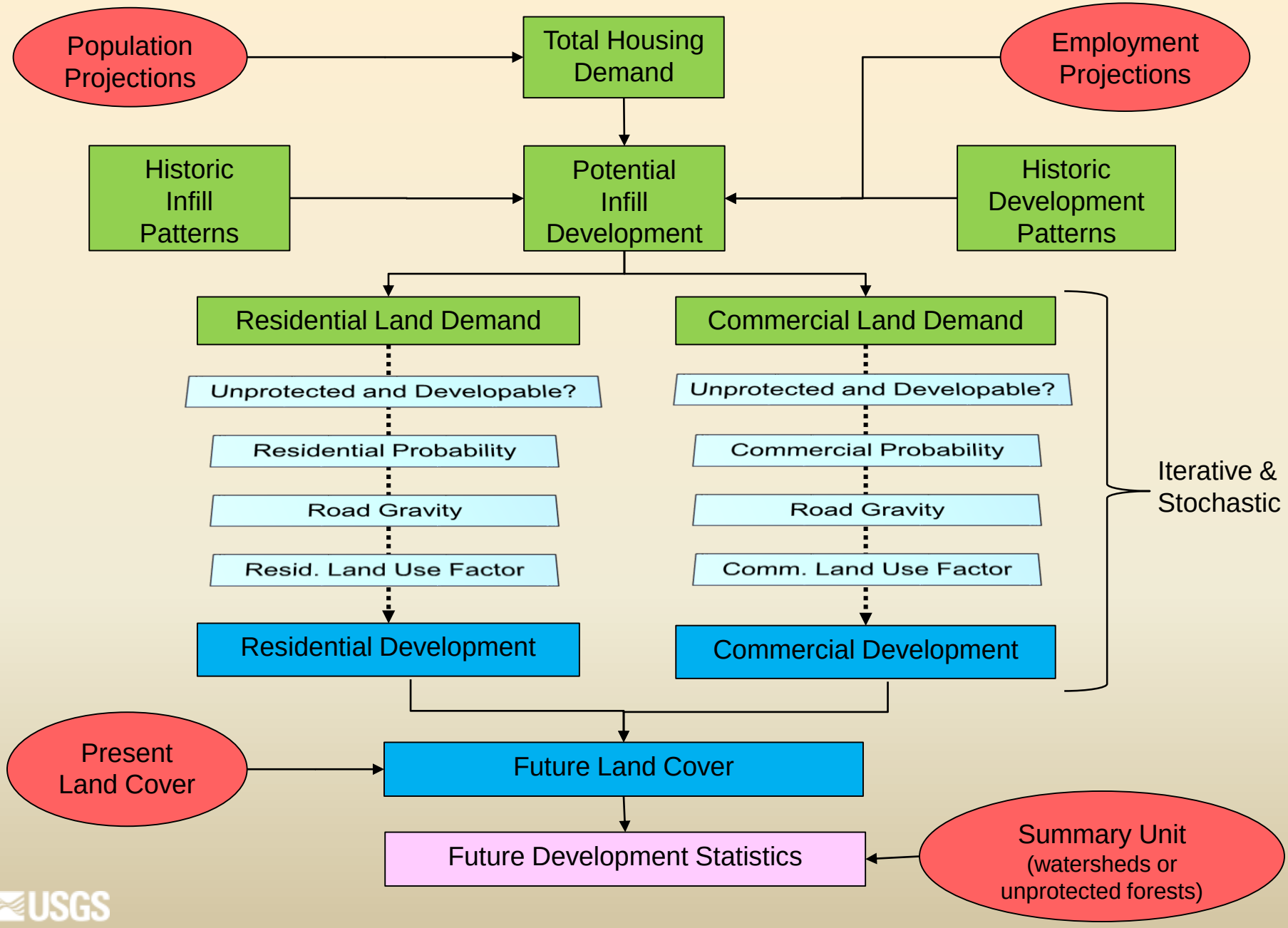
Chesapeake Bay Land Change Model v3a



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CBLCM v3a Assumptions

1. Urban growth is driven by exogenous estimates population and employment growth…

2. Growth is constrained at the county-level…

3. Growth attracts growth…

4. Residential and commercial development becomes more dense over time, increasing the most near urban areas and staying roughly constant in rural areas.

5. Historic “Infill” rates are held constant.

6. No spillover of growth from one county to another. If available land is limited, excess demand is assumed to be accommodated via infill.

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Under-detection of Land Cover Change (aka “Infill Development”)

Infill/ redevelopment = amount of development occurring within urban areas on either small vacant or already developed parcels.

Given observed growth in housing and the highest expected housing densities associated with each urban Census block, estimate expected amount of land cover change from 2000 - 2010?

Assess observed amount of land cover from 2000 – 2010?

The difference between expected and observed developed land cover change = infill/redevelopment area

Infill/redevelopment area (acres) * highest expected density (housing units/ acre) = housing units associated with infill/redevelopment.

Infill/redevelopment housing / Total housing change = Infill rate (2000 – 2010)

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Residential & Employment Growth (Howard County, MD)

Population (2010): 287,085
Population (2030): 357,100[1]

Change: 70,015 persons

Average households size (2010): 2.72
Average households size (2030): 2.72

Households in 20XX = ((Total Population – Group Housing Population) / Average Household Size)

Future Residential Housing Demand = 25,527 households

Employment (2010): 189,584[2]
Employment (2030): 259,400[3]

Change: 69,816 jobs

Future Employment Demand = 69,816 jobs

[1] MD Department of Planning, July 2014
[2] Bureau of Economic Analysis: total full and part-time employment (CA25N)
[3] MD Department of Planning, March 2014

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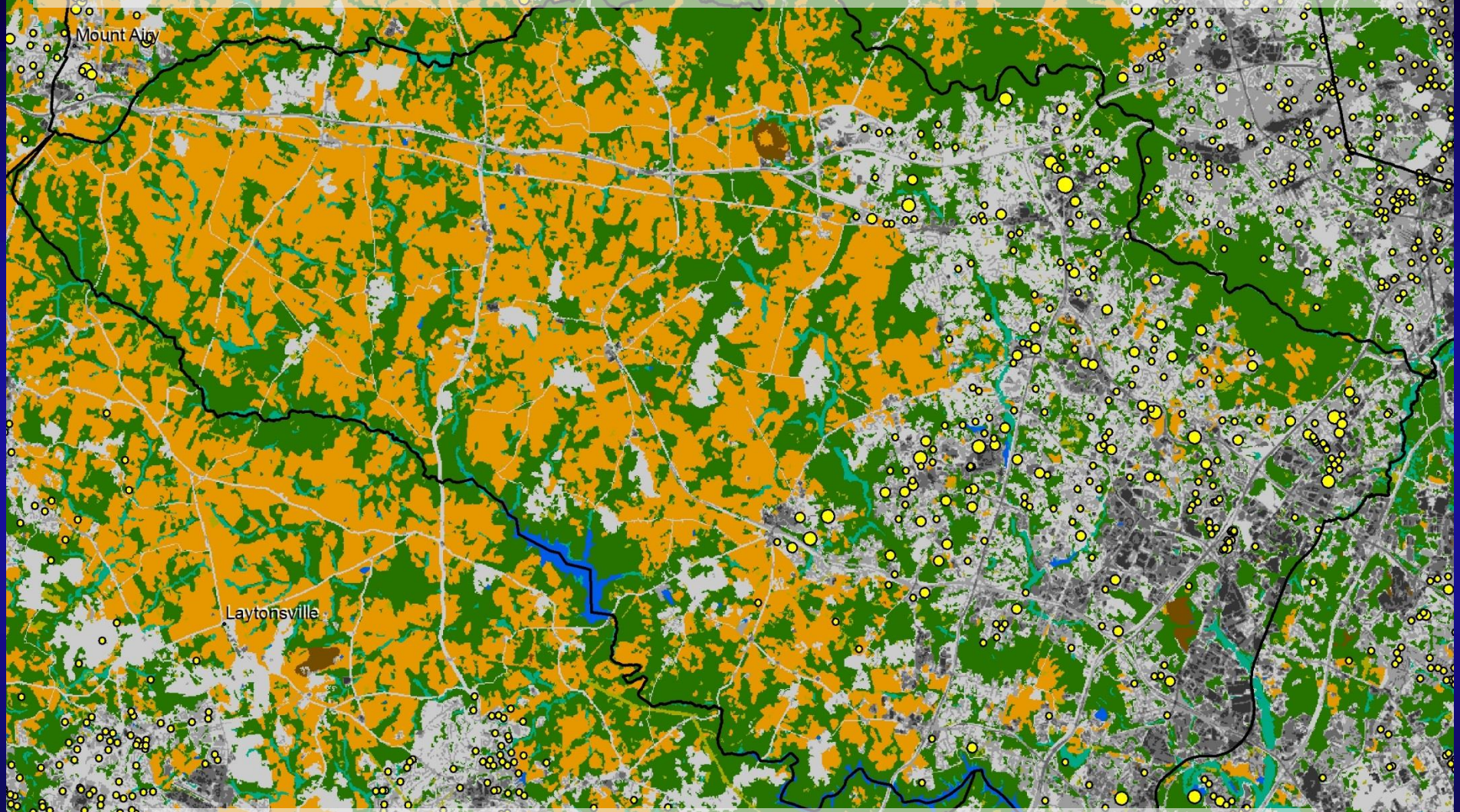
Under-detection of Land Cover Change in Howard County (aka “Infill”)



Infill Rate in Howard County (2000 – 2010) = 37%

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Housing and Employment Demand Resulting in Greenfield Development

Future Residential Housing Demand * (1- Infill Rate) = 16,018 households

Future Employment Demand * (1-Infill Rate) = 43,810 jobs

Forest and farm area converted to development depend on:

a. Future housing and employment demand;

b. Land available for development;

c. Residential and commercial densities in areas where growth is forecast to occur;

d. Spatial distribution of forest and farmland.

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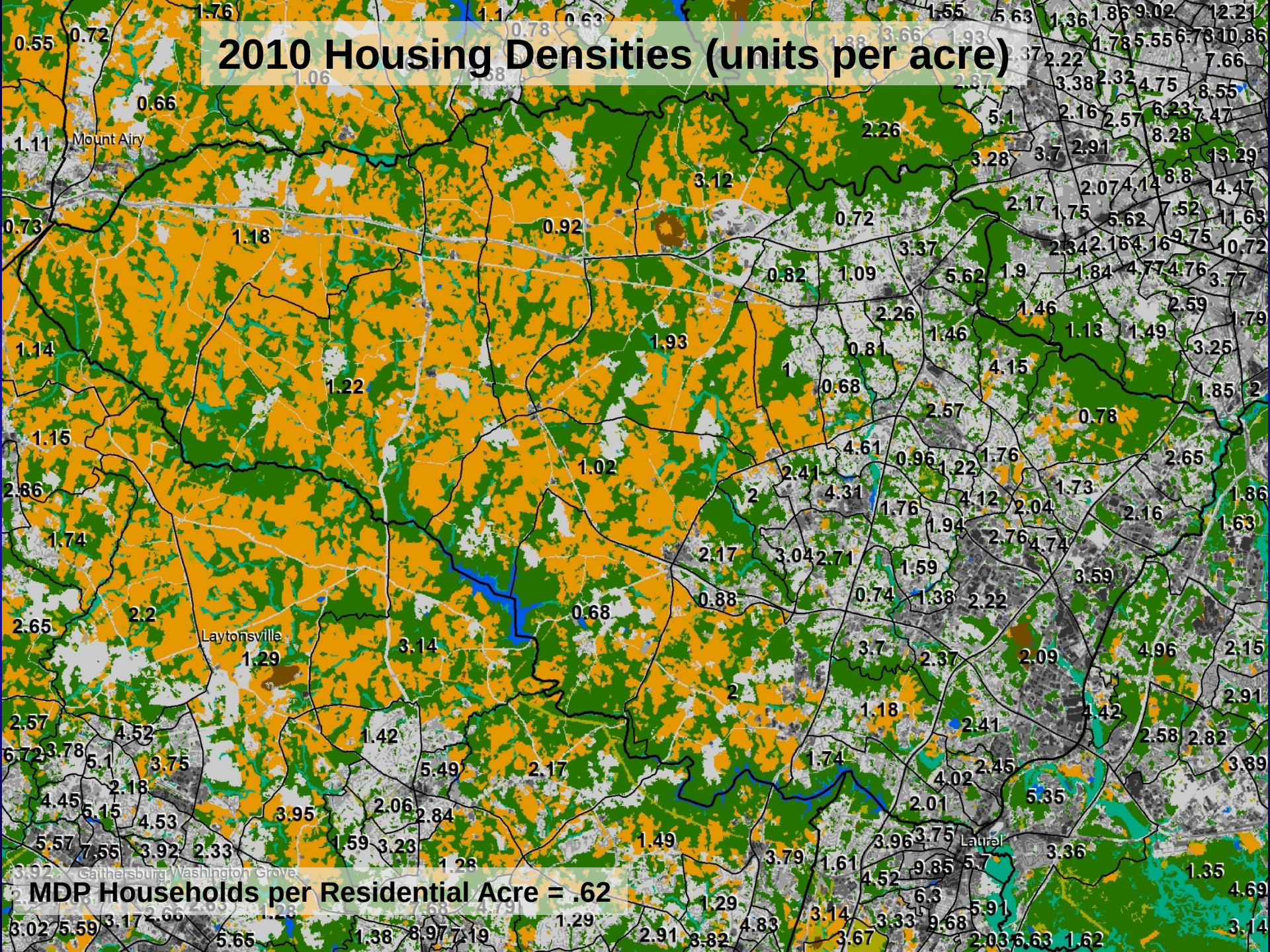
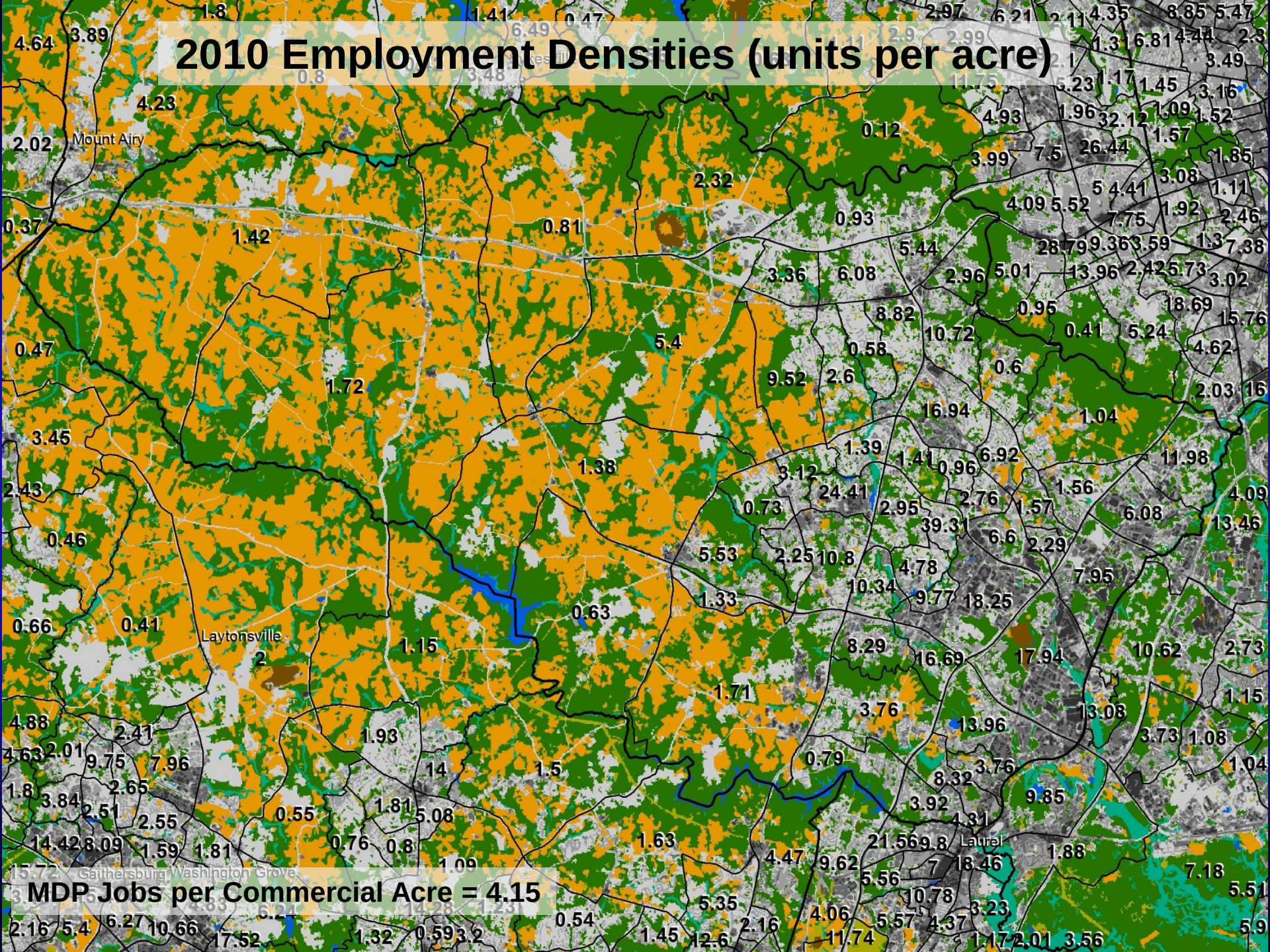
2010 Housing Densities (units per acre)



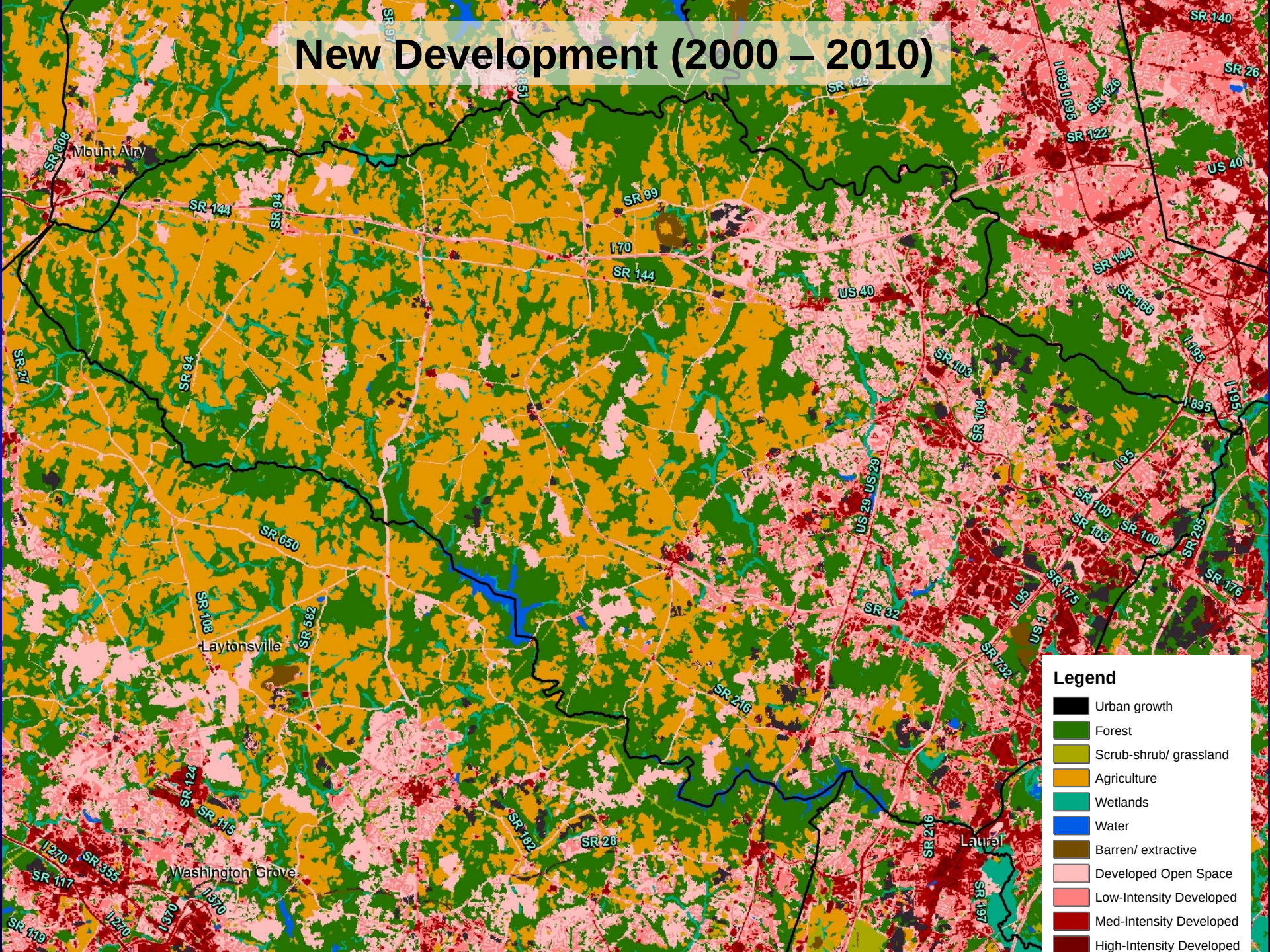
MDP Households per Residential Acre = .62

2010 Employment Densities (units per acre)

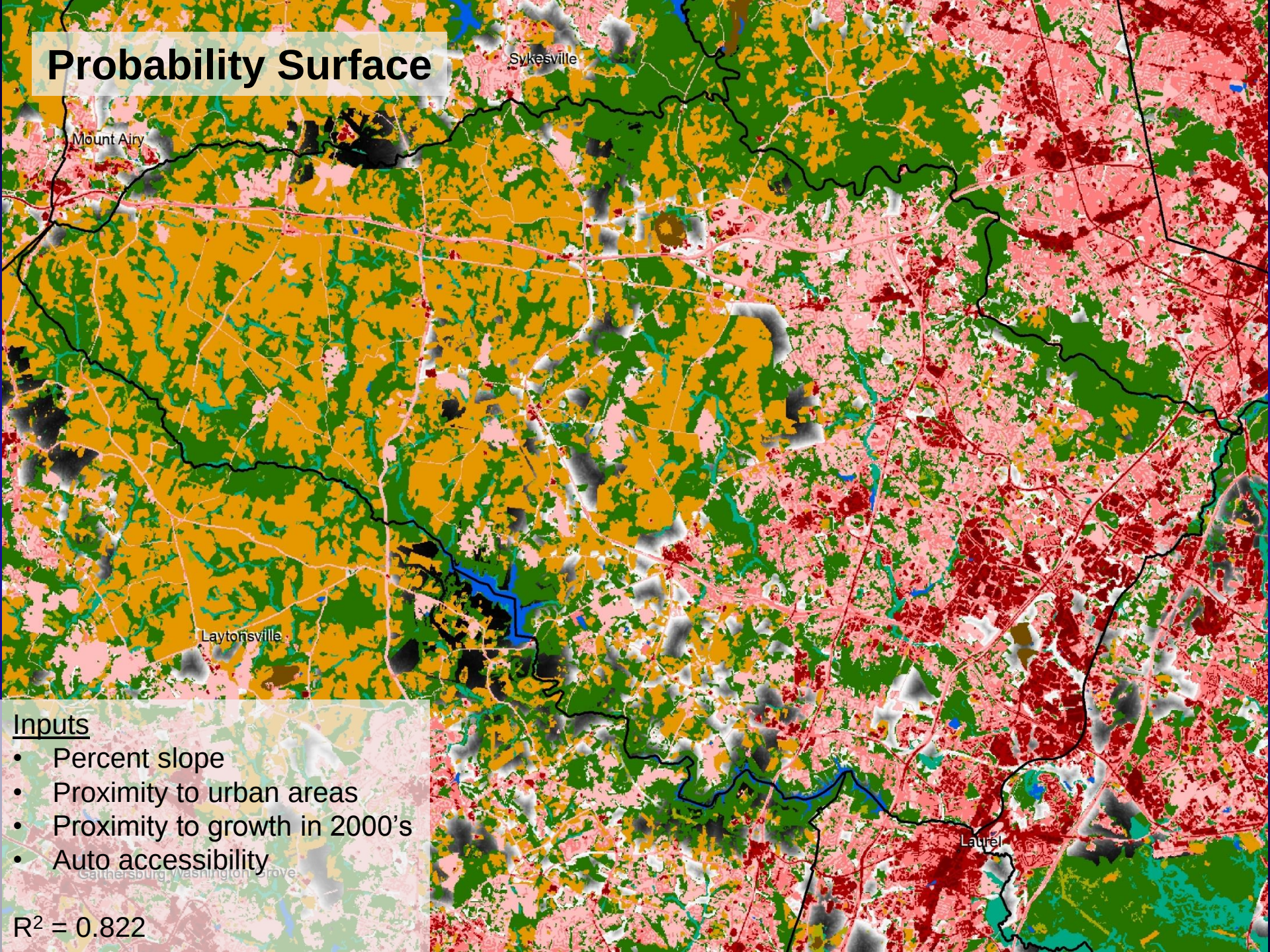


MDP Jobs per Commercial Acre = 4.15

New Development (2000 – 2010)



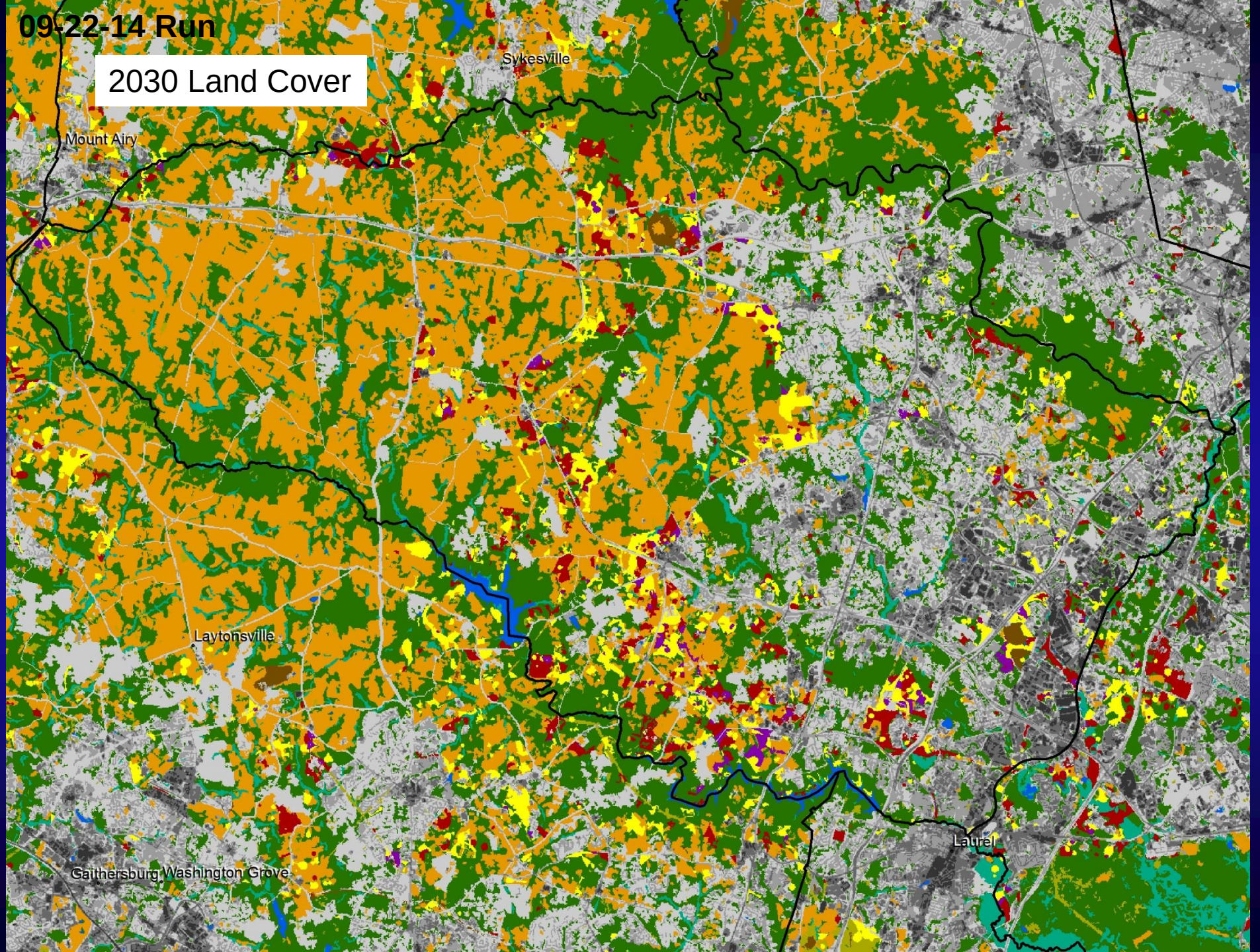
Probability Surface

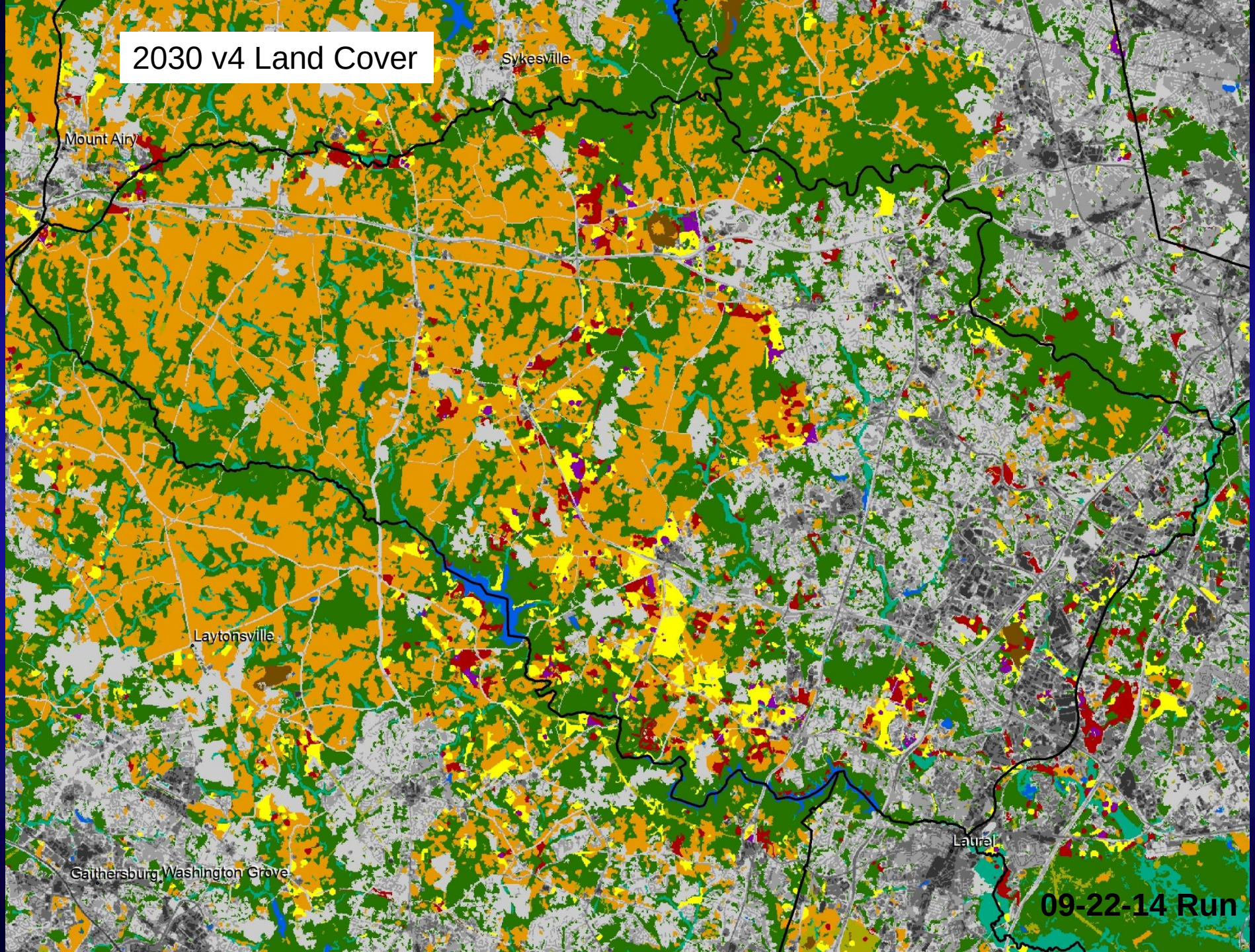


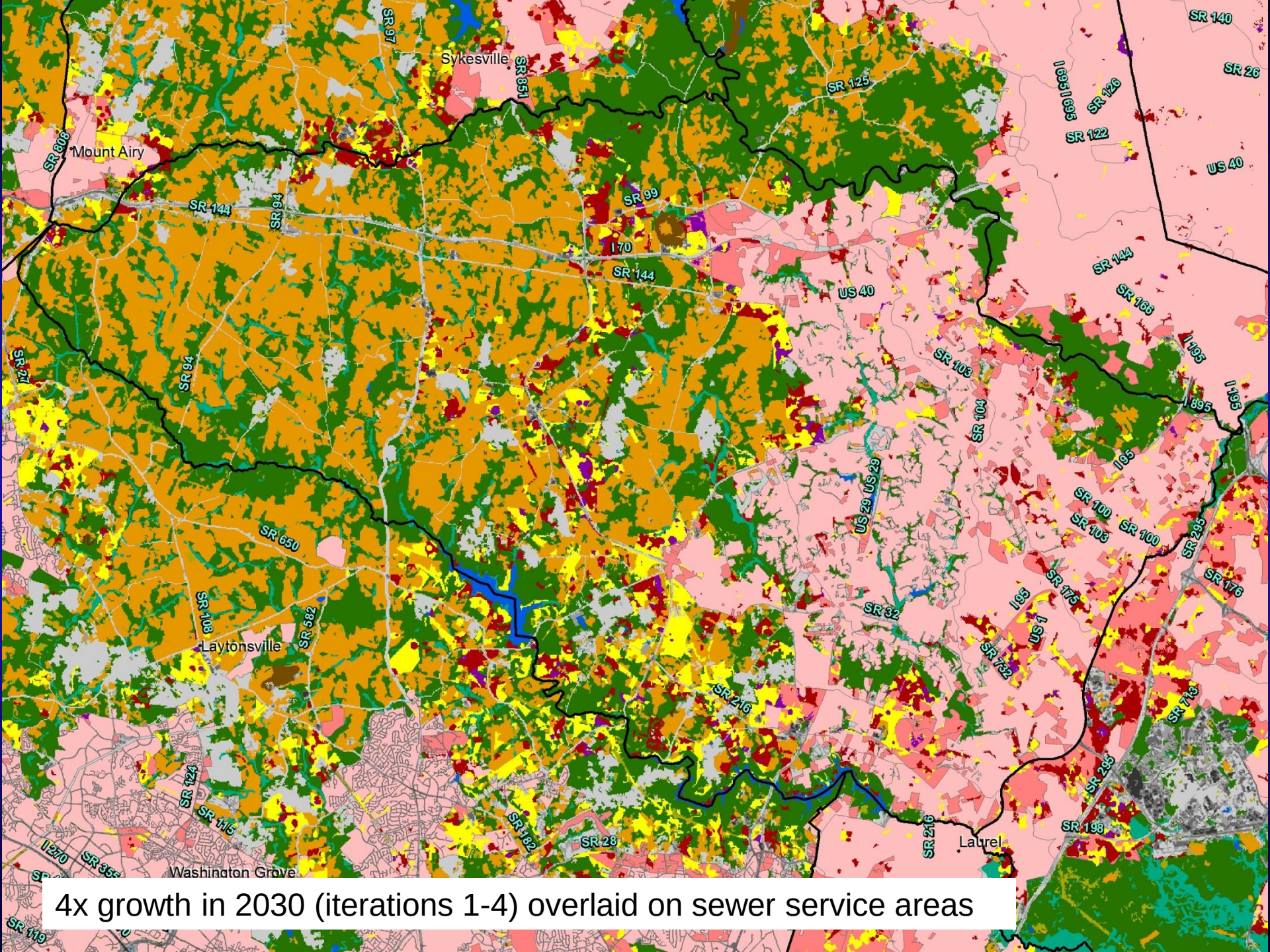
Inputs

- Percent slope
- Proximity to urban areas
- Proximity to growth in 2000's
- Auto accessibility

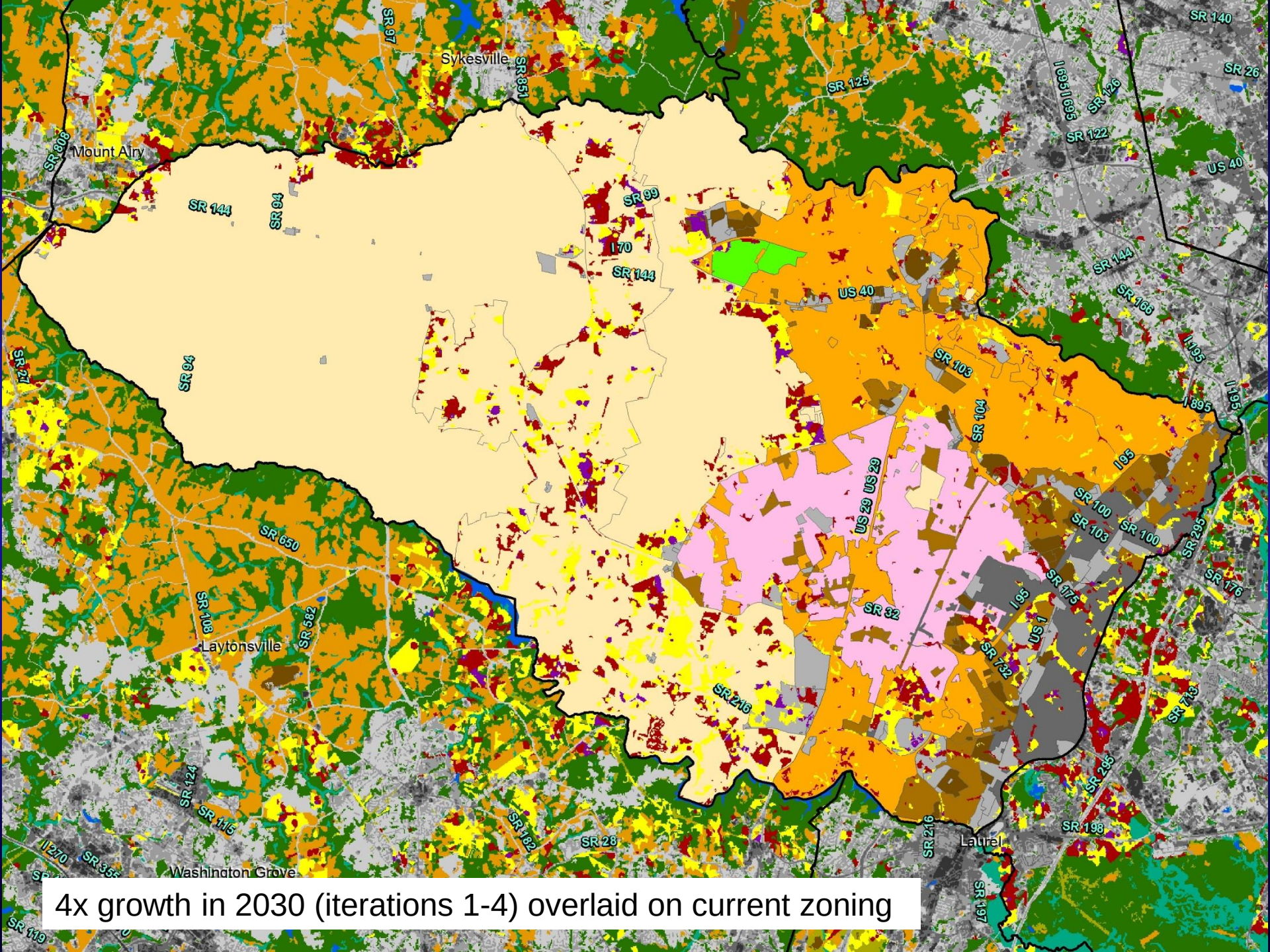
$R^2 = 0.822$


09-22-14 Run
2030 Land Cover
Sykesville
Mount Airy
Laytonsville
Laurel
Gaithersburg
Washington Grove

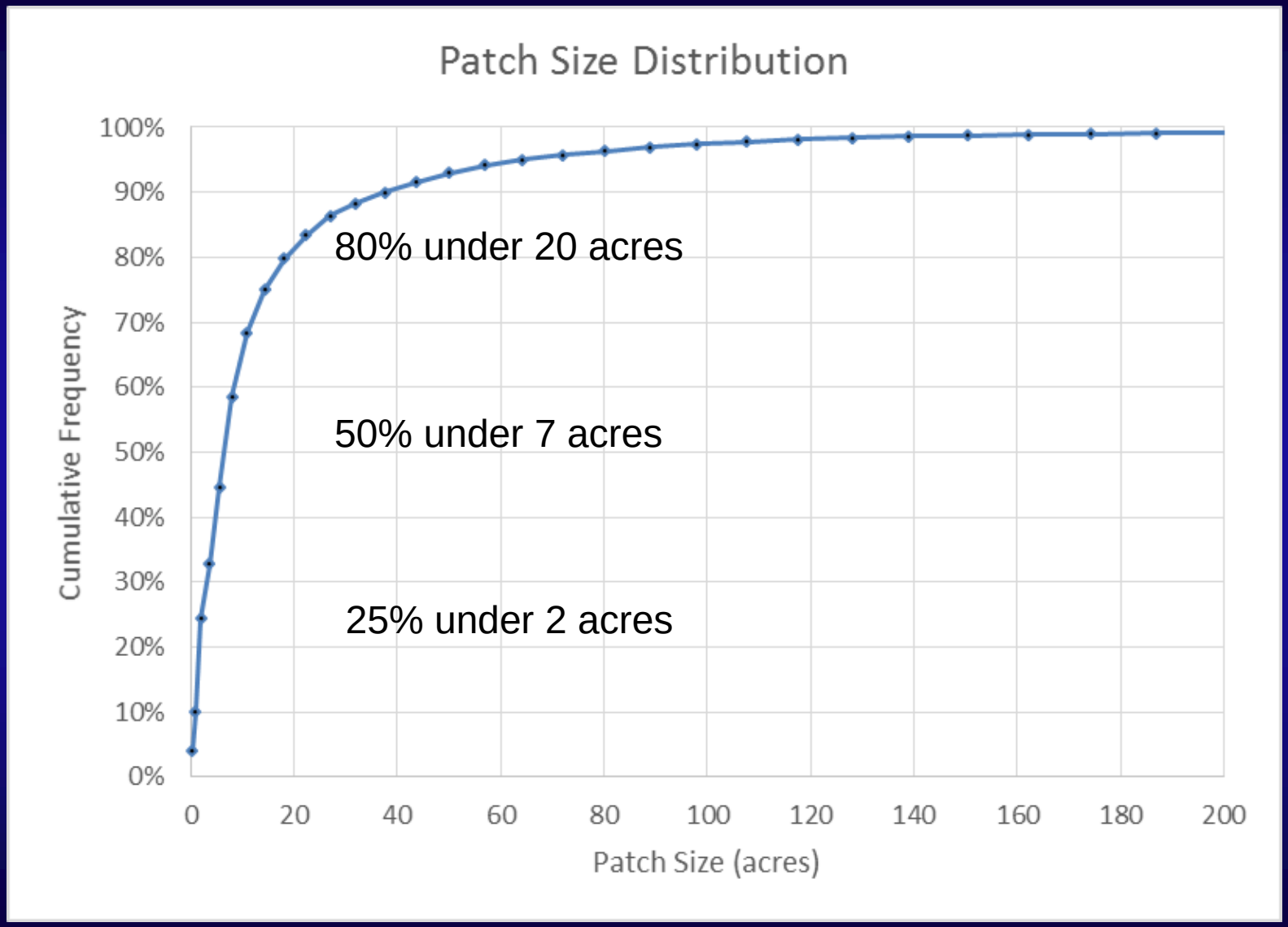

2030 v4 Land Cover
Sykesville
Mount Airy
Laytonsville
Gaithersburg
Washington Grove
Laurel
09-22-14 Run



4x growth in 2030 (iterations 1-4) overlaid on sewer service areas



4x growth in 2030 (iterations 1-4) overlaid on current zoning


Patch Size Distribution
Cumulative Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
20
40
60
80
100
120
140
160
180
200
Patch Size (acres)
80% under 20 acres
50% under 7 acres
25% under 2 acres

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Nutrient and Sediment Land Use Loads

Example: What is the total nitrogen load from a new 100-acre residential development on a parcel of fully developable land that is currently 50% forest (conserved), 50% farmland, 100% on septic and has a potential density of 0.5 dwelling units per acre.

Impervious and pervious developed area of parcel:

0.5 units/acre = 2 acre lots
100 acres/ 2-acre lots = 50 households
10.6% impervious[1] * 100 acres = 10.6 acres impervious & 89.4 acres pervious

Pre-development load:

Farmland area (50 acres) * farmland TN load (17.6 lbs/acre/yr) +
Forest area (50 acres) * forest TN load (3.5 lbs/acre/yr)
1 household * septic[2] TN load (7.01 lbs/household/yr)
= 887 TN lbs/yr

Post-development load:

Impervious area (10.6 acres) * impervious TN load (13.2 lbs/acre/yr) +
Pervious area (39.4 acres) * pervious TN load (8.5 lbs/acre/yr) +
Forest area (50 acres) * forest TN load (3.5 lbs/acre/yr)
50 households * septic[2] TN load (7.01 lbs/household/yr)
= 1,000 TN lbs/yr

Net change: + 113 TN lbs/yr (+363 TN lbs/yr without forest conservation)

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[1] Cappiella and Brown, 2001
[2] Assumes 65% efficiency of septic systems

Nutrient and Sediment Loading Coefficients

	Total Nitrogen (lbs./acre/year)				
	Impervious	Pervious	Construction	Forest	Agriculture
MD (median)	10.5	7.8	17.1	2.2	16.9
Howard (mean)	13.2	8.5	24.9	3.5	17.6
	Total Phosphorus (lbs./acre/year)				
	Impervious	Pervious	Construction	Forest	Agriculture
MD (median)	1.3	0.3	3.1	0.1	1.3
Howard (mean)	1.4	0.3	4.3	0.1	2.0
	Total Suspended Sediment (lbs./acre/year)				
	Impervious	Pervious	Construction	Forest	Agriculture
MD (median)	507	76	2,576	36	391
Howard (mean)	1,425	222	6,295	219	1,335

Impervious Surface Coefficients*	
Residential Lot Size (acres)	Impervious
2	10.6%
1	14.3%
0.5	21.2%
0.25	27.8%
0.125	32.6%
0.0625	44.4%
Commercial	72.2%

* Cappiella and Brown, 2001

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Net Nutrient and Sediment Land Use Loads

2030 Trend Scenario for Howard County

Changes in Pollutant Loads (lbs) due to Forecasted Development (2010 - 2030)							
Pollutant	Impervious	Pervious	Construction	Forest	Agriculture	Development	Net
Nitrogen	1,923,228	1,462,701	646,746	412,856	707,009	4,119,611	2,999,747
Phosphorus	208,473	53,398	113,015	8,955	404,810	374,886	-38,879
Sediment	207,468,939	38,311,242	163,651,586	25,632,714	268,162,848	409,431,767	115,636,204

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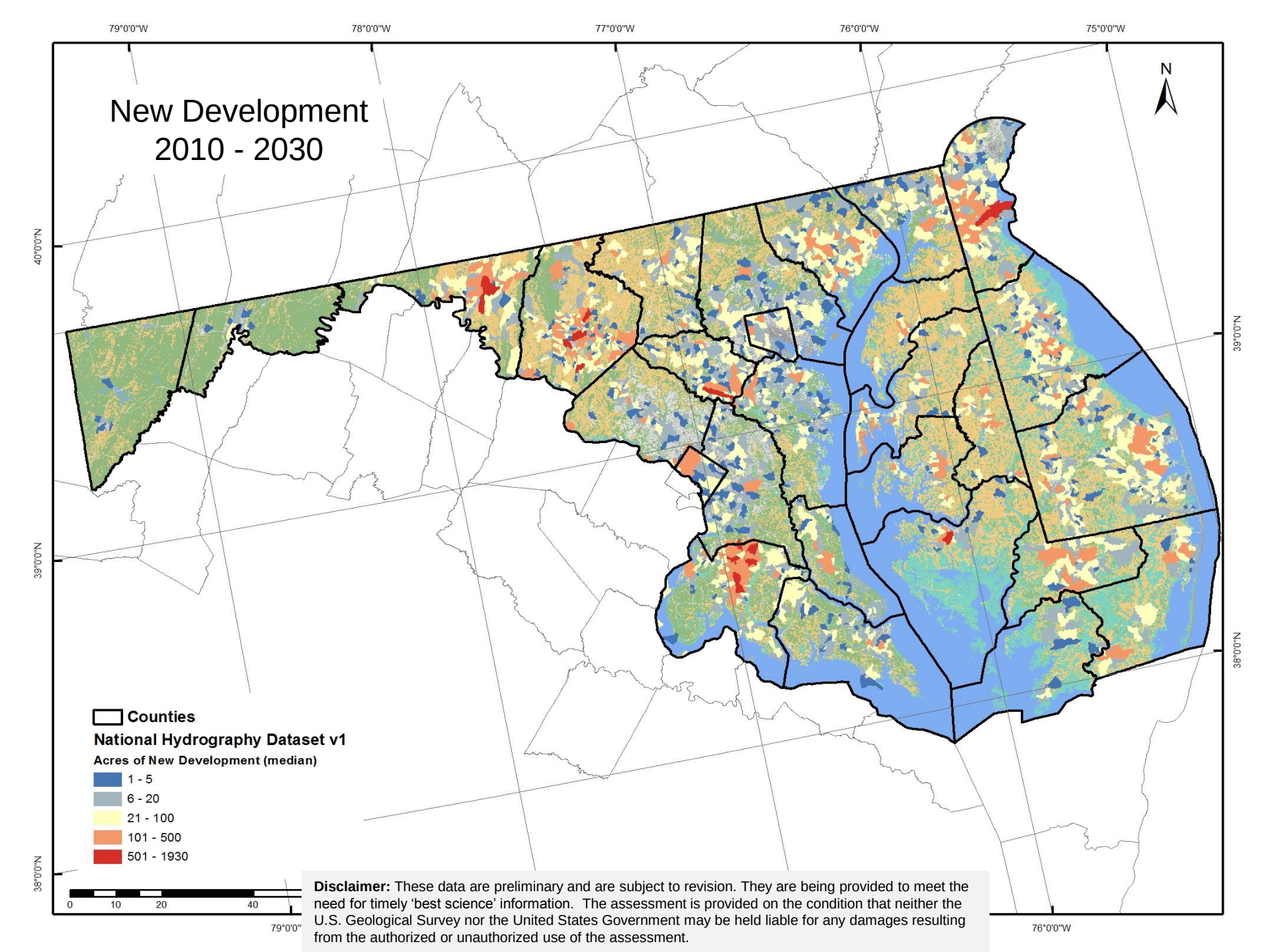

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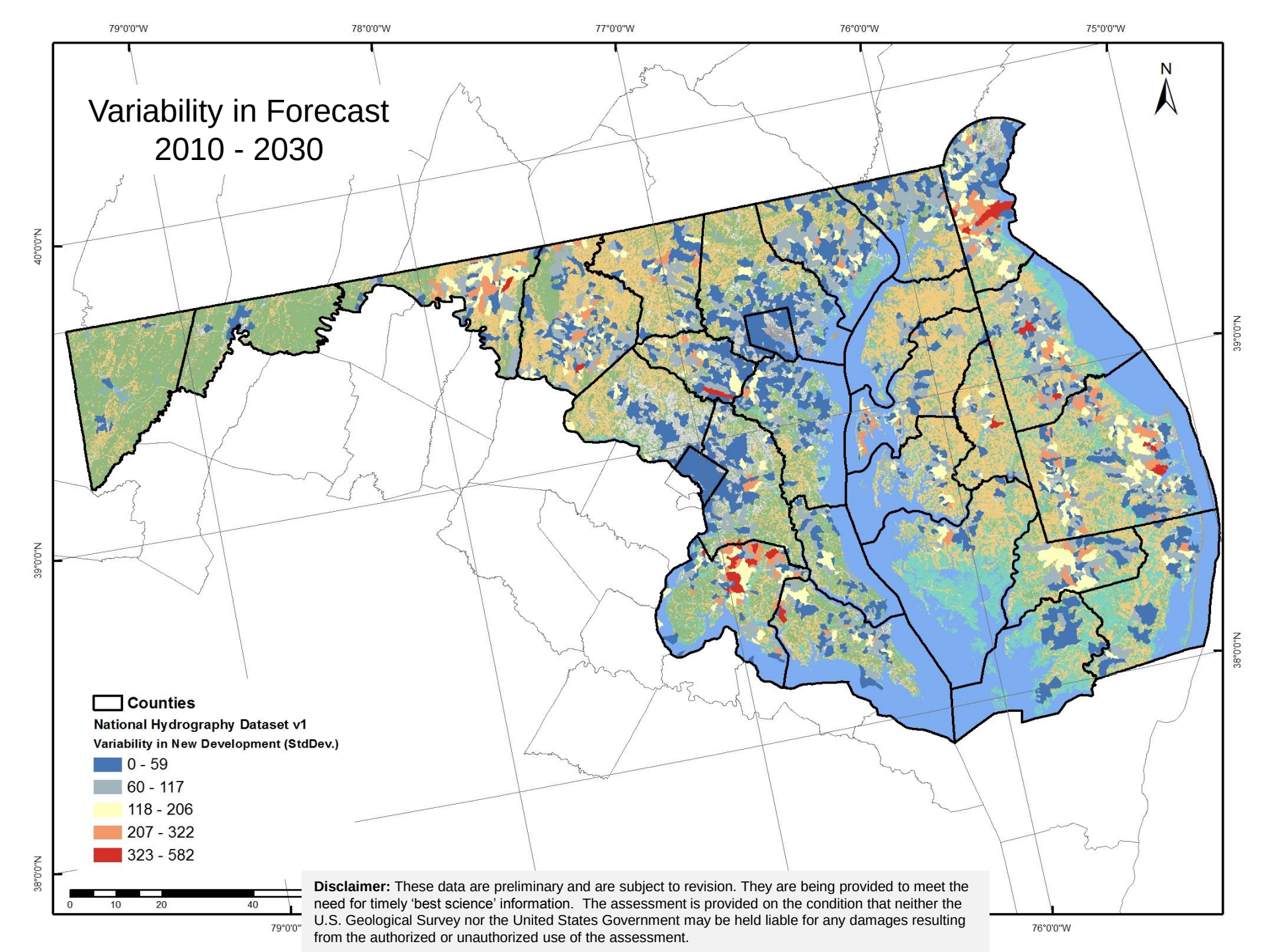

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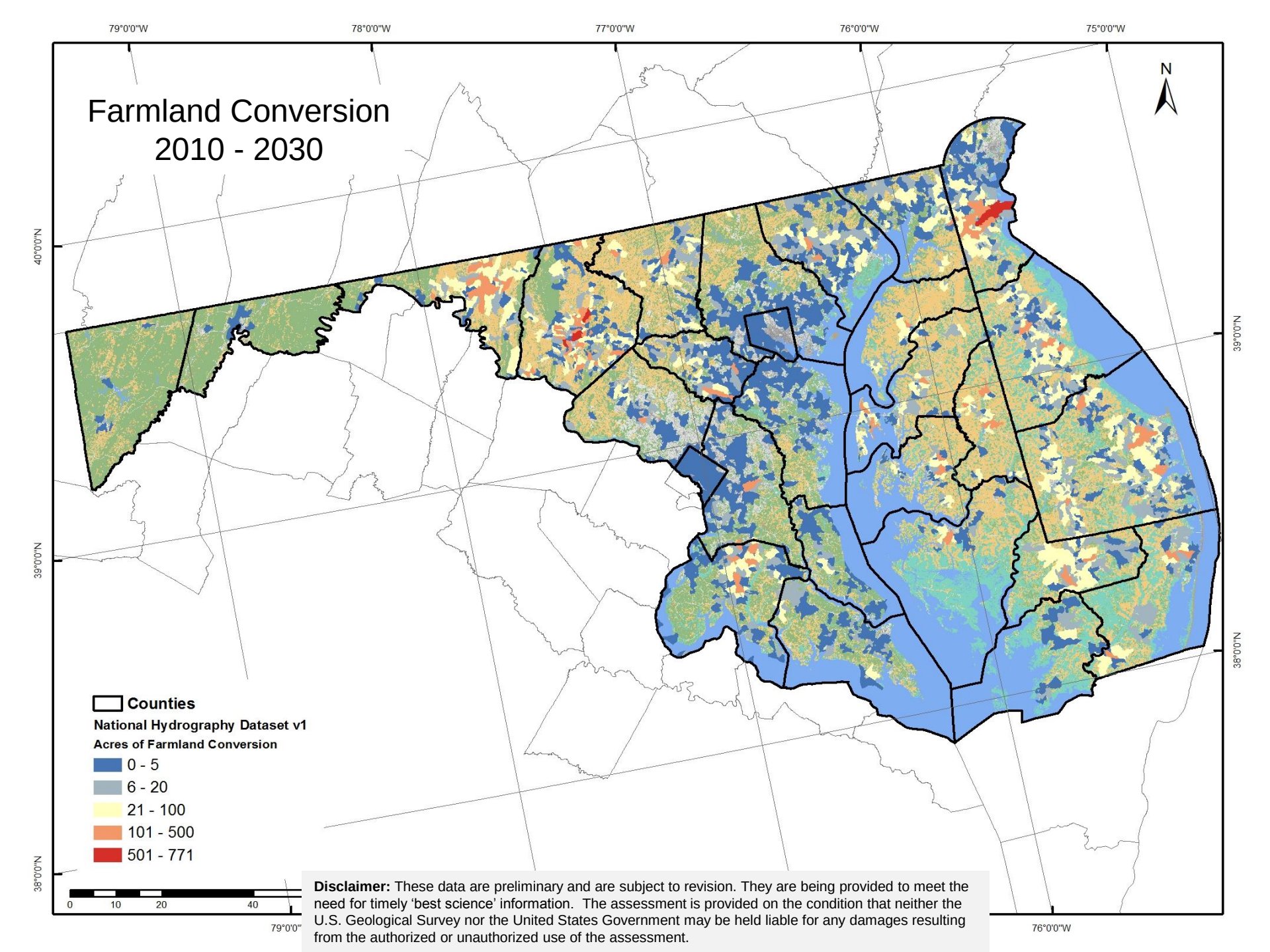

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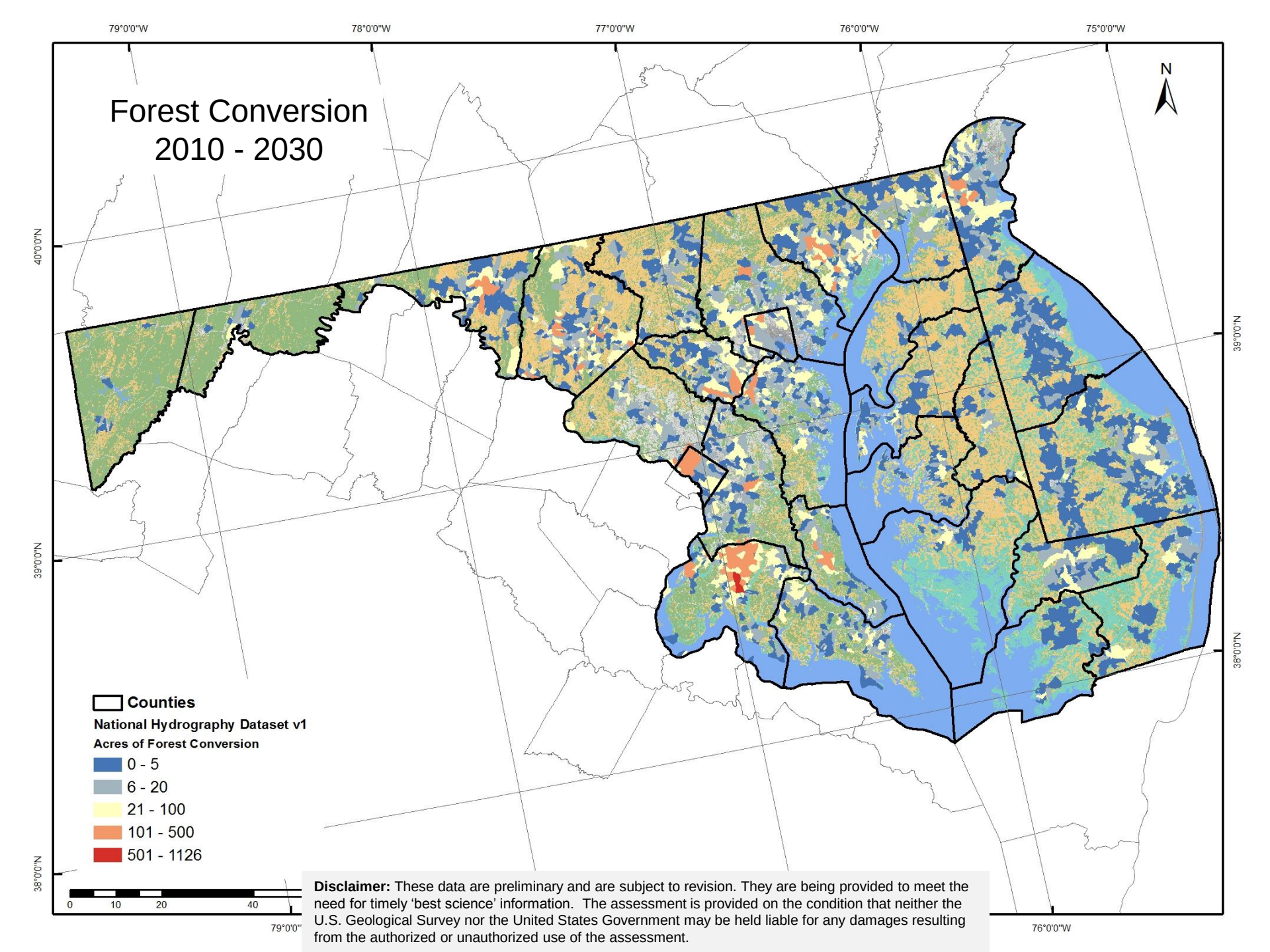

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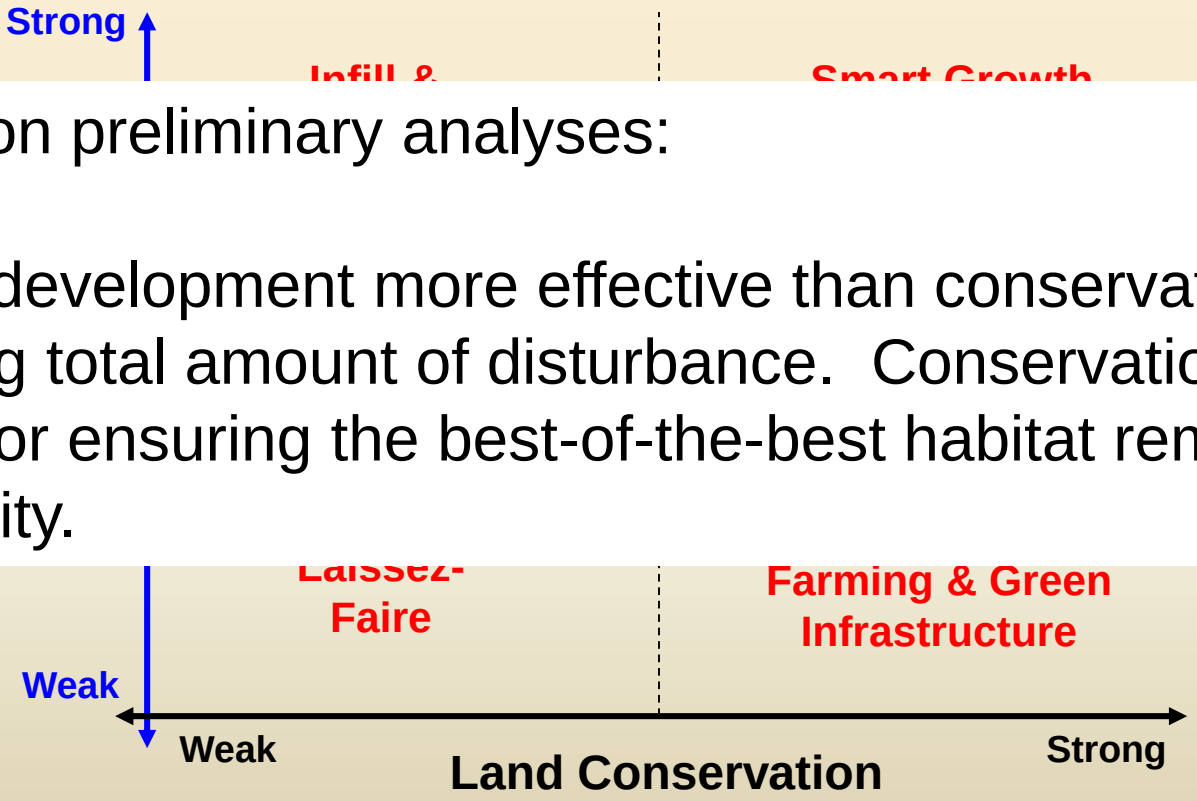
Potential Alternative Future Scenarios



Based on preliminary analyses:

Infill/ redevelopment more effective than conservation in reducing total amount of disturbance. Conservation only option for ensuring the best-of-the-best habitat remains in perpetuity.

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Assessing Vulnerability

Vulnerability = *ƒ* (exposure, sensitivity, and resilience)

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Assessing the Vulnerability of Forested Watersheds

Threats =

- urban development, shale gas extraction, insects and pests, climate change

Sensitivity =
(threat specific)

- Species tolerance of fragmentation, invasives, low water table, soil compaction, prolonged drought.

Resilience =
(i.e., adaptive capacity or ability to recover)

- Species ability to shift habitat/range, conserve water, extend roots to lowered water table, maintain recruitment in understory.

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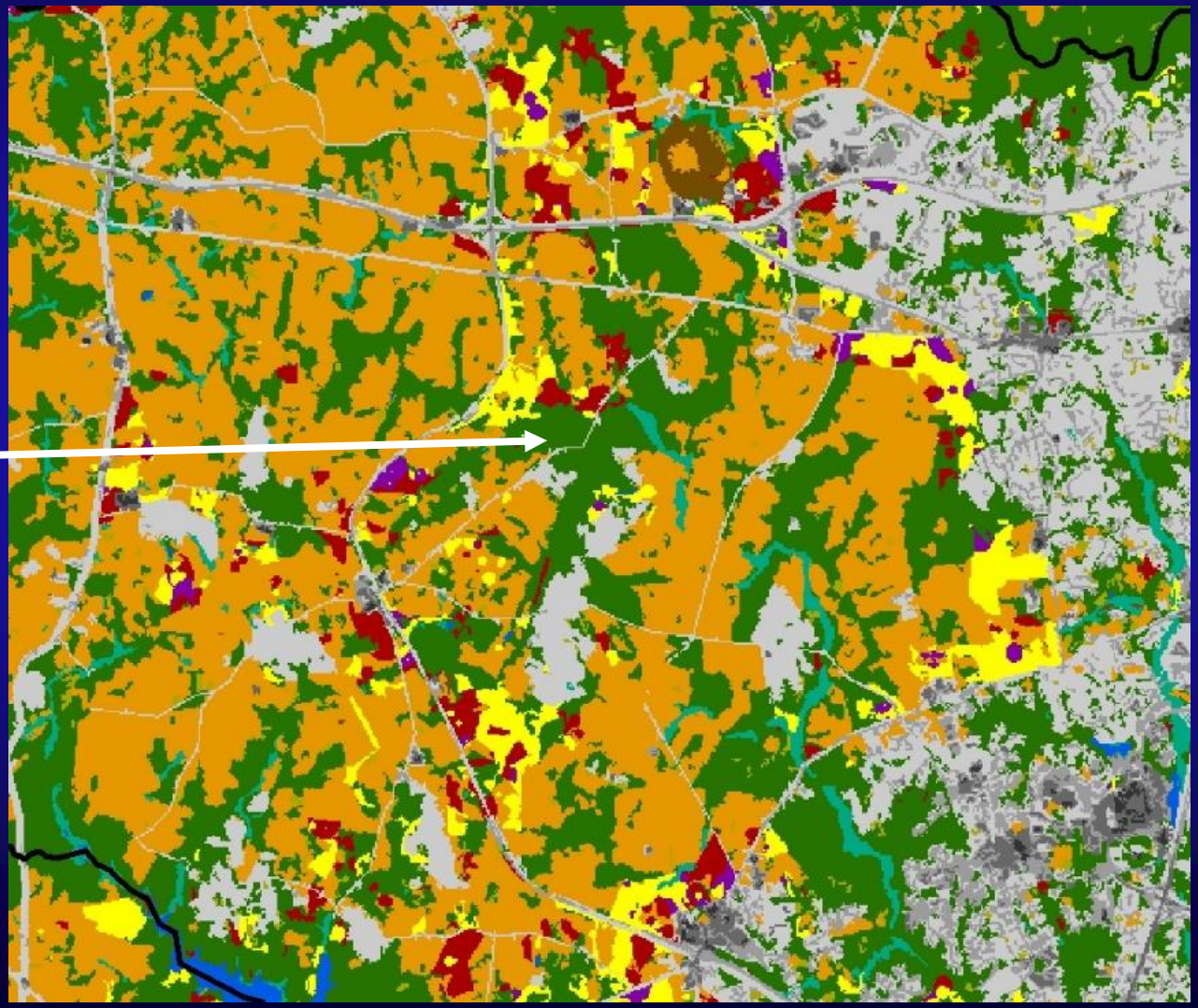
Assessing Vulnerability to Development 2.0

What is the likelihood and magnitude of forest loss for each unprotected patch of forest? Under a range of scenarios?



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Crediting Conservation in the TMDL
(following REDD convention)

1. Set the Phase III WIPS on a 2025 land use.

2. Estimate the probable amount of forest conversion to development (e.g., 75% probability of 100 acres conversion).

3. Estimate the change in N,P, and TSS loads from conversion.
   = potential amount of “avoidance” that could be credited.

4. Estimate the change in probability and acreage of conversion due to conservation, enforced zoning, incentivized infill, and other scenarios.

5. Translate change in probability and acreage to a credit for avoided loads under each scenario.

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Help from STAR?

1. Estimating changes in nutrient and sediment loads from land conversion.

2. Quantifying water quality credits under conditions of uncertainty.

3. Assessing the utility of high-resolution land cover to address CBP tracking and monitoring objectives.

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