Chesapeake Bay Land Change Model (CBLCM) Applications for Phase 7 and Revised Bay Agreement

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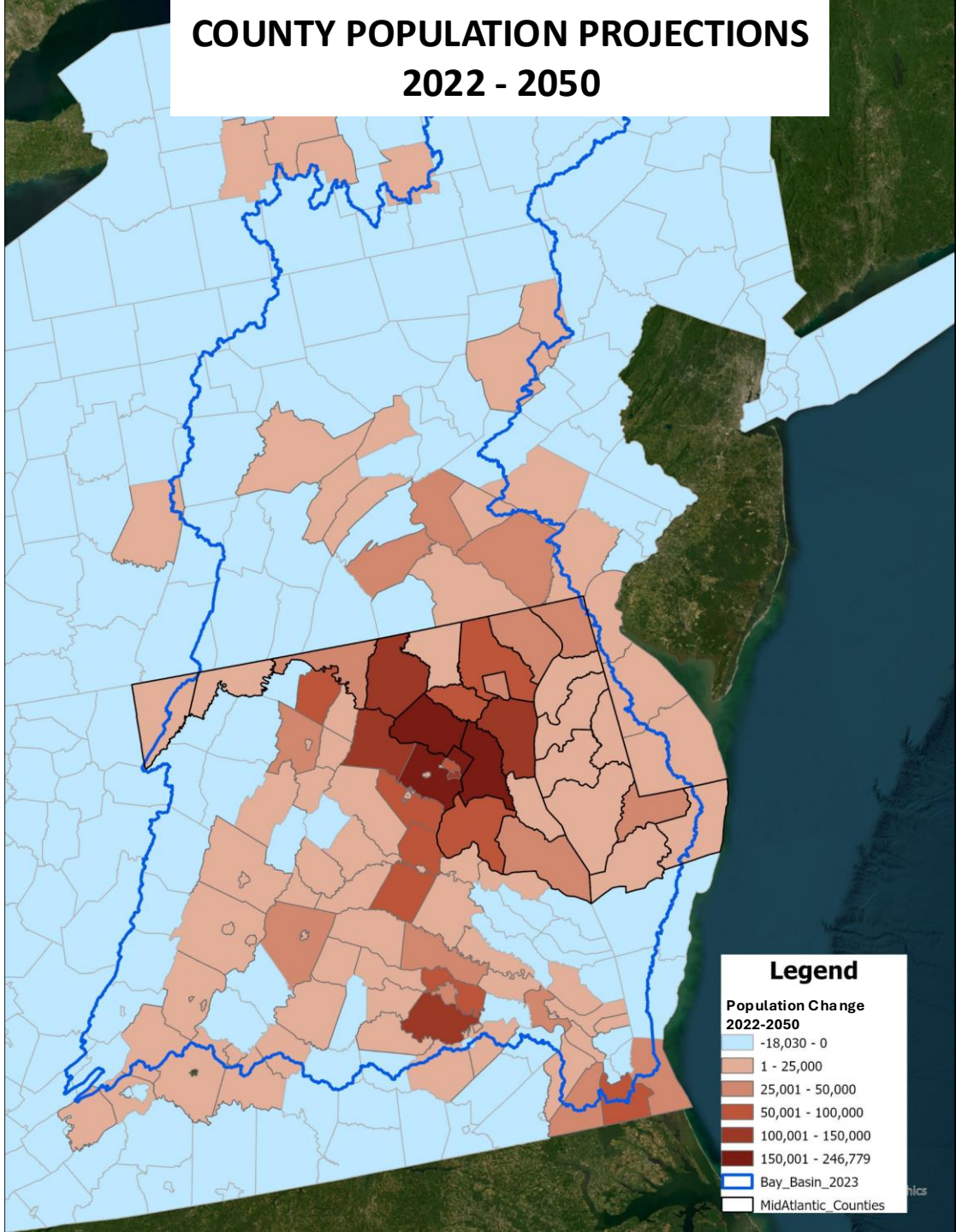
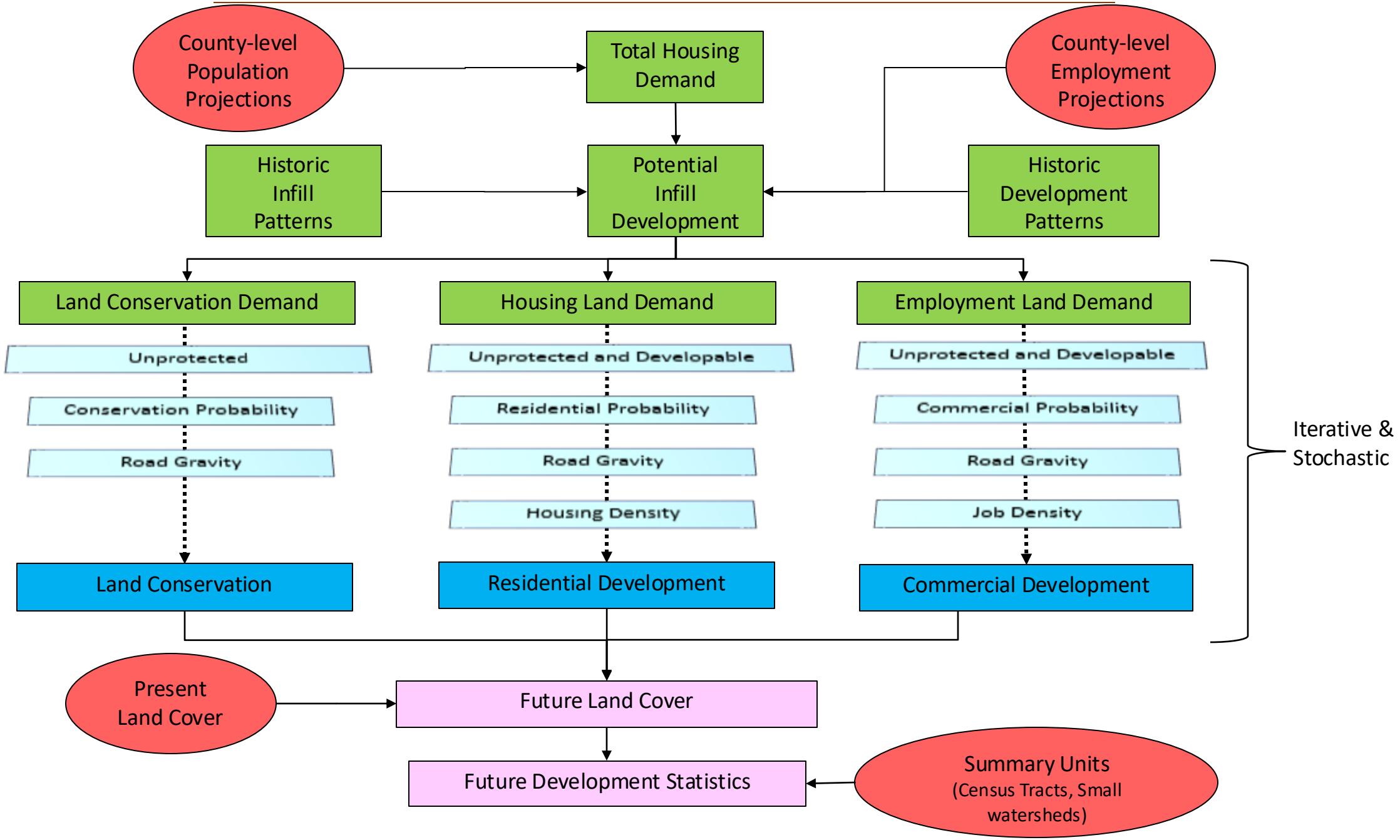
Modeling the Effects of Population Growth on Land Use Change and Pollutant Loads

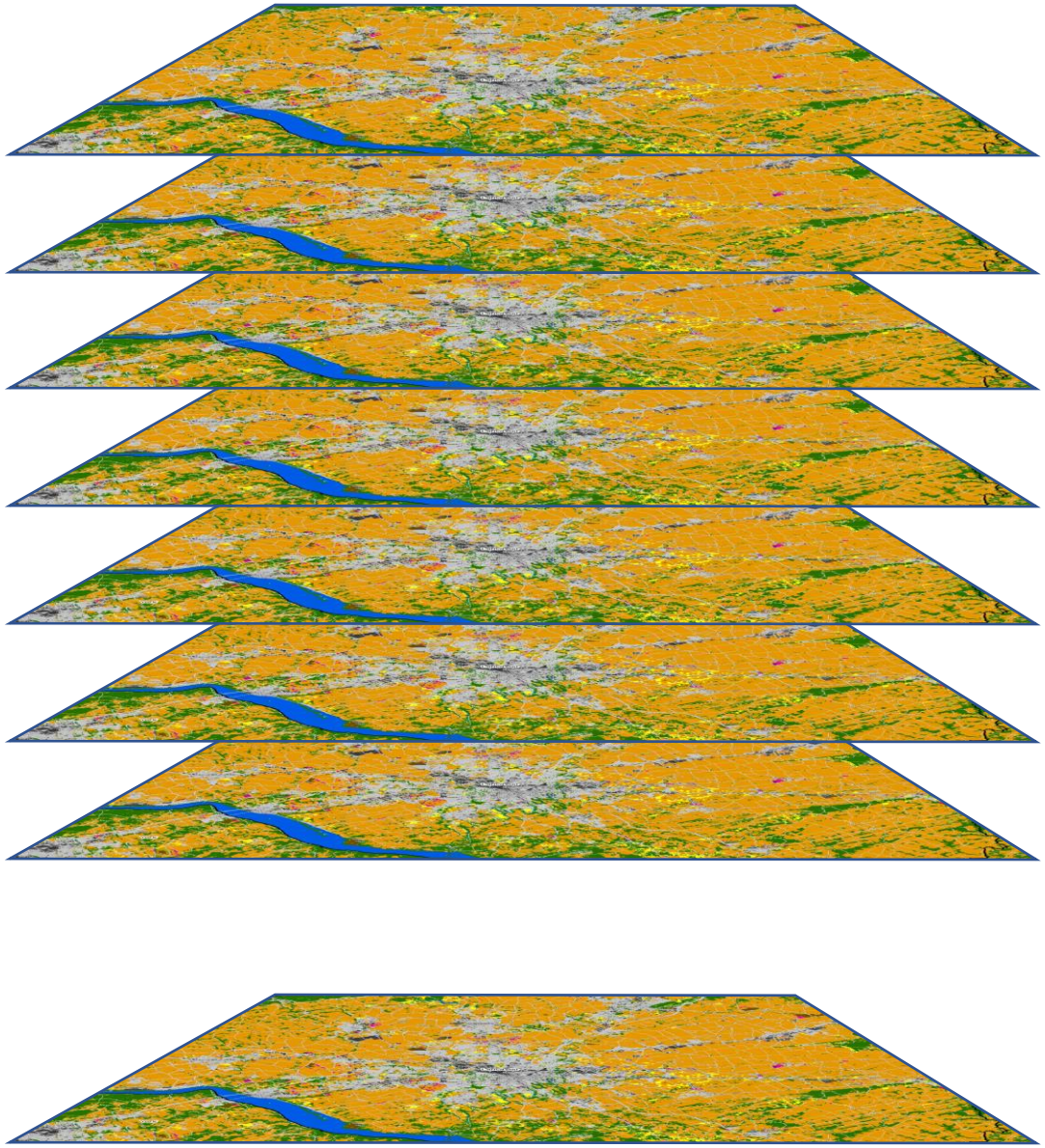
State	Population 2022-2050
DC	26%
DE	3%
MD	20%
NY	-9%
PA	3%
VA	23%
WV	24%
Total	17%



Chesapeake Bay Land Change Model v5



Multiple Stochastic Iterations



Every county is simulated 101 times for each scenario and target year, i.e., 2025.

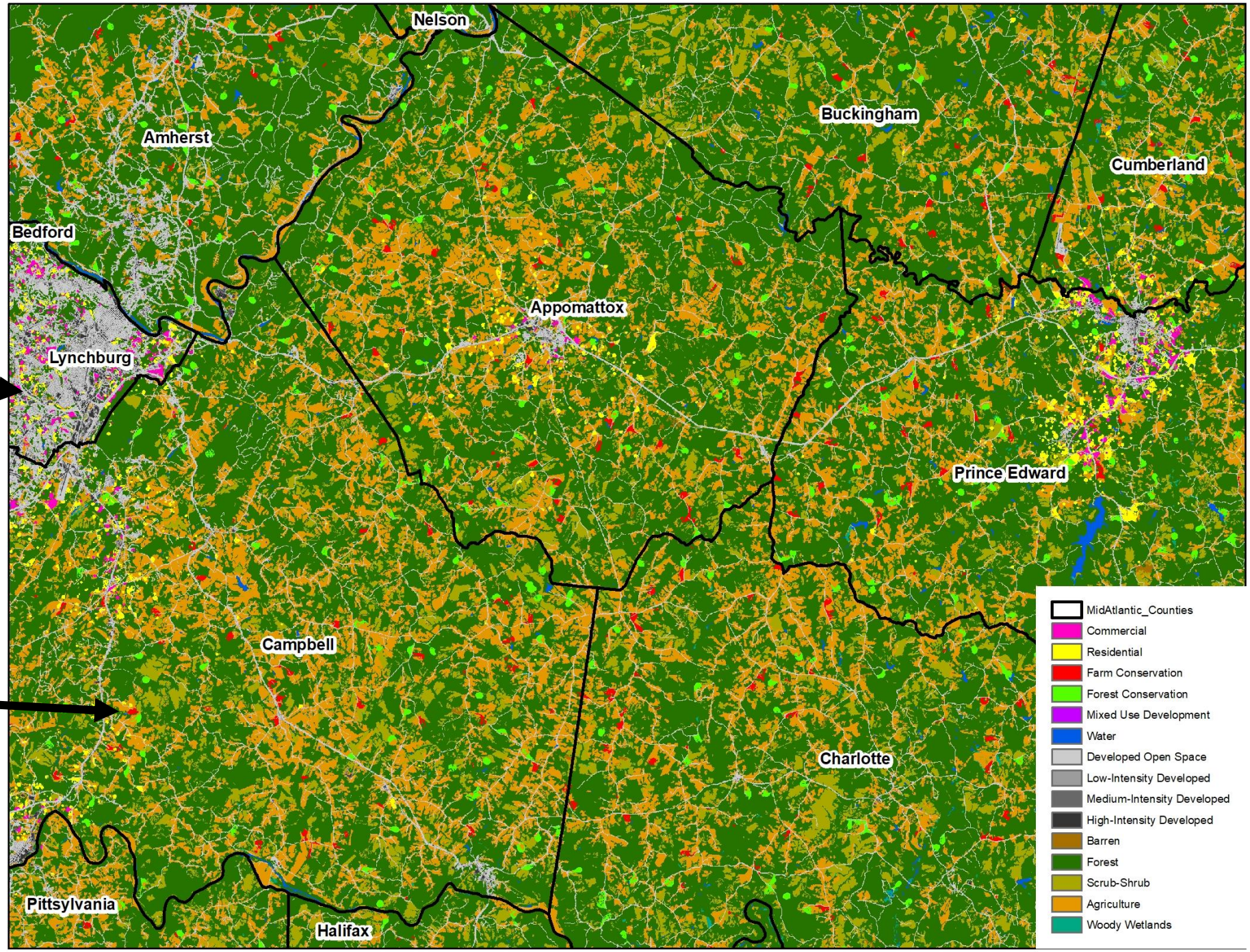
Average of simulations by summary unit = future development

Relative Standard Deviation = estimate of uncertainty

Land Change Model Outputs

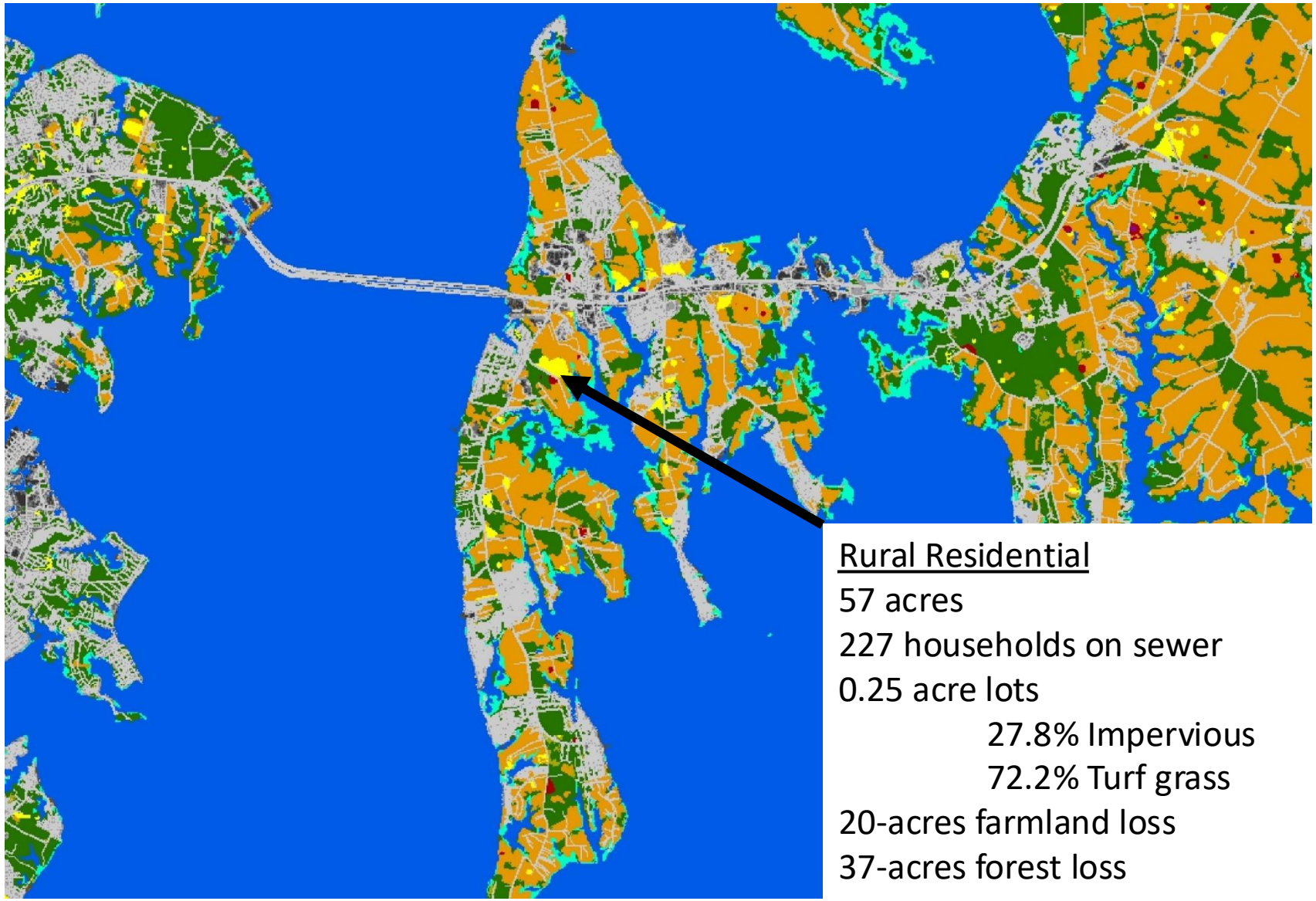
Commercial and Residential Growth

Farmland and Forest Conservation



Land Change Model Outputs: Summary Statistics

- Impervious surface and turf grass expansion
- Forest conversion to development
- Farmland conversion to development
- Future population on sewer and septic



<u>Rural Residential</u>
57 acres
227 households on sewer
0.25 acre lots
27.8% Impervious
72.2% Turf grass
20-acres farmland loss
37-acres forest loss

Simulated Future Scenarios

Historic Trends (HT)

The HT scenario assumes that the forces, policies, and regulations that influenced development patterns over the 2000's will continue unabated into the future.

Current Zoning (CZ)

The CZ scenario builds on the HT scenario by restricting residential and commercial growth to areas explicitly zoned for these uses or mixed-use development where such zoning exists.

Growth Management (GM)

The GM scenario builds on the CZ scenario and represents a move towards the implementation of smart growth policies that serve to densify and concentrate growth in areas with sufficient infrastructure and services to support it.

Forest Conservation (FC)

The FC scenario also builds on the CZ scenario and represents immediate implementation of aggressive natural land conservation zoning, ordinances, easements, and acquisition.

Agricultural Conservation (AC)

The AC scenario builds on the CZ scenario and represents immediate implementation of aggressive agricultural land conservation zoning, ordinances, easements, and acquisition.

“Conservation Plus” BMP Elements

FOREST CONSERVATION

- Conserve riparian zones (default width = 30m)
- Conserve wetlands (NWI, State Designated Wetlands, and Potential Conservable Wetlands (PA only))
- Conserve all lands subject to inundation due to sea level rise (default = 1m rise by the year 2100)
- Conserve all lands surrounding National Wildlife Refuges (default = 1 mile buffer)
- Conserve all large forest tracts (default >= 250 acres)
- Conserve Bay shorelines (default = 305m buffer (~1000-ft) of the tidal Bay and Atlantic shorelines)
- Conserve all high-value forest and forested wetlands identified by the Chesapeake Conservation Partnership

GROWTH MANAGEMENT

- Increase proportion of growth occurring as infill/redevelopment (default = 10% per decade)
- Increase urban densities (default = 10% per decade)
- Increase proportion of urban vs rural growth (default = 10% per decade)
- Expand sewer service areas (default = ~1 mile))
- Avoid growth on all soils unsuitable for septic systems (based on depth to bedrock, drainage class, saturated hydraulic conductivity, and flood frequency)

FARMLAND CONSERVATION

- Conserve all farmland within designated Agricultural Districts
- Conserve all lands within the floodplain (default = 100-year recurrence interval)
- Conserve all lands with flooded soils (default = frequently flooded)
- Conserve all prime farmlands and farmland of state importance
- Conserve potential restorable wetlands (applies only to PA farmland)
- Conserve all high-value farmland identified by the Chesapeake Conservation Partnership

Forecasted Land Use Change in Maryland, 2013-2025, under five different scenarios

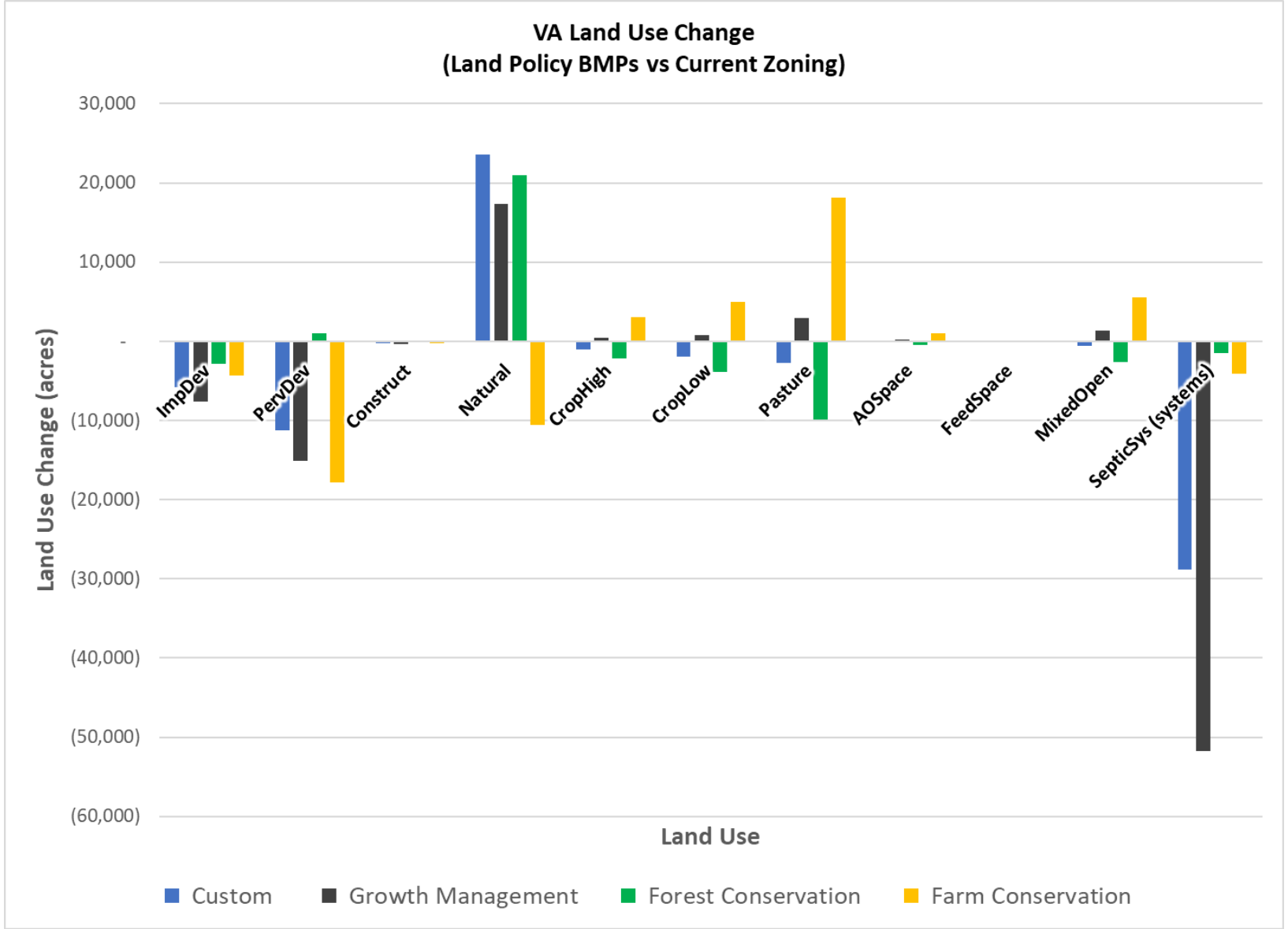
Claggett, et al., 2023.

Land Policy BMP
Land Use Implications

- Increase in natural lands
- Decrease in impervious and pervious development
- Decrease in housing units on septic

Land Use/Load Source Abbreviations

Ag Open Space	Construction	CropLow	CropHigh	PervDev	ImpDev	FeedSpace	MixedOpen	Natural	Other	Pasture
AOS	CNS	CPL	CPH	PRV	IMP	FDS	MO	NAT	OTH	PAS
AOSpace	Regulated Construction	Full Season Soybeans	Double Cropped Land	Non-Regulated Turf Grass	MS4 Tree Canopy over Impervious	Permitted Feeding Space	Mixed Open	True Forest	Stream Bed and Bank	Pasture
	CSS Construction	Other Agronomic Crops	Specialty Crop High	Non-Regulated Tree Canopy over Turf Grass	MS4 Roads	Non-Permitted Feeding Space	CSS Mixed Open	Non-tidal Floodplain Wetland	Shoreline	Other Hay
		Small Grains and Grains	Silage with Manure	MS4 Turf Grass	MS4 Buildings and Other			Headwater or Isolated Wetland		Legume Hay
		Specialty Crop Low	Grain without Manure	MS4 Tree Canopy over Turf Grass	CSS Tree Canopy over Impervious			Harvested Forest		Riparian Pasture Deposition
			Grain with Manure	CSS Turf Grass	CSS Roads			CSS Forest		
			Silage without Manure	CSS Tree Canopy over Turf Grass	CSS Buildings and Other					
					Non-Regulated Tree Canopy over In					
					Non-Regulated Roads					
					Non-Regulated Buildings and Other					

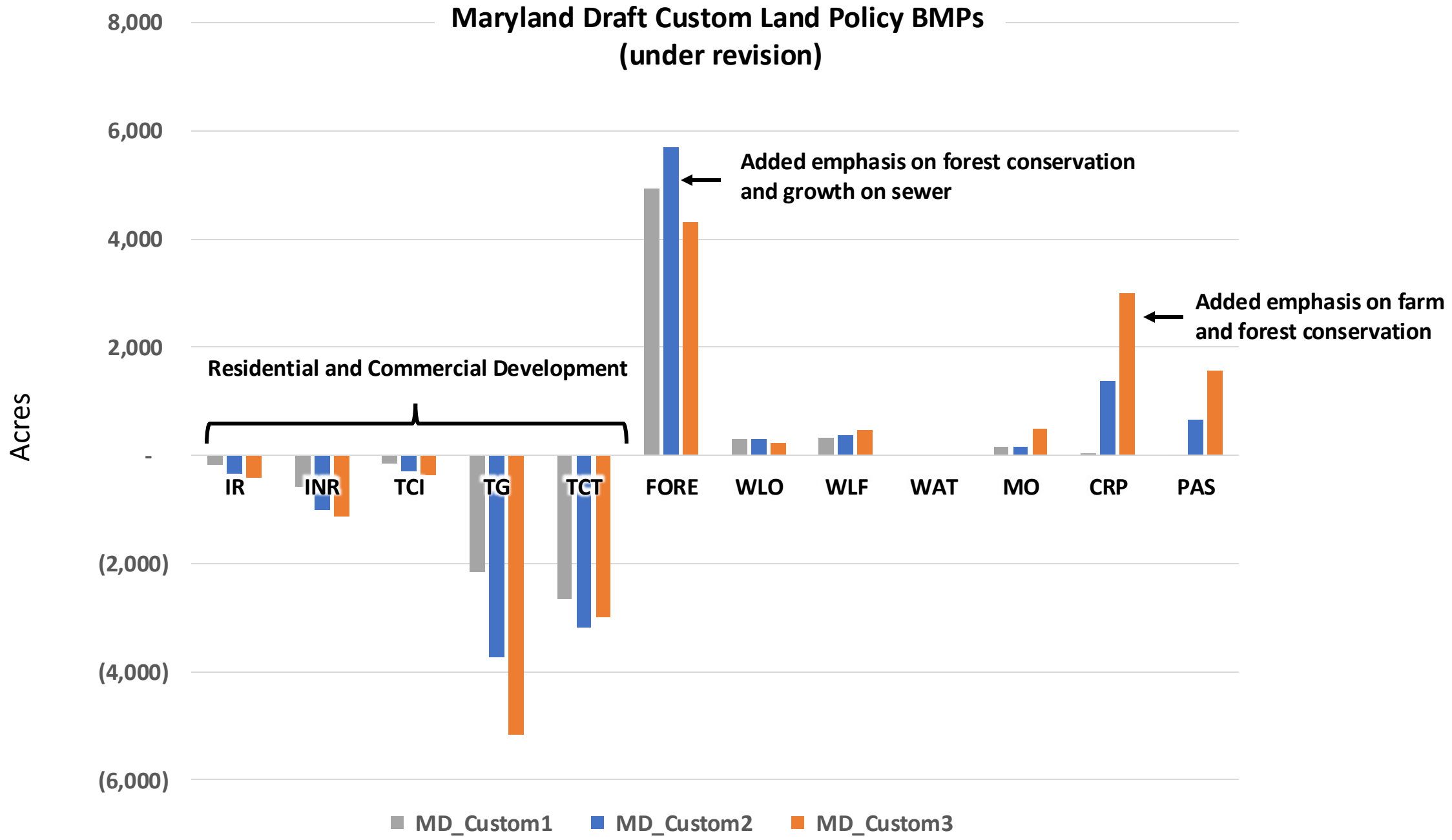


LandPolicyBMP	ImpDev	PervDev	Construct	Natural	CropHigh	CropLow	Pasture	AOSpace	FeedSpace	MixedOpen	SepticSys (systems)
Custom	(5,837)	(11,264)	(242)	23,584	(1,007)	(1,944)	(2,706)	19	-	(599)	(28,821)
Growth Management	(7,573)	(15,146)	(329)	17,369	448	741	2,958	161	-	1,335	(51,740)
Forest Conservation	(2,890)	1,027	107	21,005	(2,187)	(3,905)	(9,903)	(490)	-	(2,684)	(1,494)
Farm Conservation	(4,290)	(17,789)	(204)	(10,557)	2,986	4,964	18,155	976	-	5,574	(4,150)

Custom Land Policy BMPs

Maryland (Current Regulatory Scenario):

- Conserve riparian zones (width = 30m)
- Conserve wetlands (NWI)
- Conserve Resource Conservation Areas and Wetlands of Special State Concern
- Establish maximum residential densities based on local and state regulations
- Stochastically conserve farmland within 30m riparian zone based on expected County-level rates of CREP participation (acres)
- Stochastically conserve 15% of undeveloped land within modeled urban areas.
- Stochastically conserve forests by County based on participation in state programs and land trust activities
- Stochastically conserve farmland by County based on participation in state programs


Maryland Draft Custom Land Policy BMPs
(under revision)
8,000
6,000
4,000
2,000
-
(2,000)
(4,000)
(6,000)
Acres
Residential and Commercial Development
Added emphasis on forest conservation and growth on sewer
Added emphasis on farm and forest conservation
IR
INR
TCI
TG
TCT
FORE
WLO
WLF
WAT
MO
CRP
PAS
MD_Custom1
MD_Custom2
MD_Custom3

Land Policy BMP Results
Summary

DC			
LandPolicyBMP	TN	TP	TSS
DC Custom (draft)	303	27	58,219
Growth Management	(88)	(10)	(14,255)
Forest Conservation	(133)	(15)	(21,471)
Farmland Conservation	(27)	(2)	(4,078)

DE			
LandPolicyBMP	TN	TP	TSS
DE Custom (draft)	30,050	(2,826)	(122,264)
Growth Management	(26,372)	(202)	(28,066)
Forest Conservation	(1,050)	(77)	(57,551)
Farmland Conservation	28,501	(1,414)	40,912

MD			
LandPolicyBMP	TN	TP	TSS
MD Custom (draft)	(111,926)	(6,317)	(6,722,178)
Growth Management	(156,504)	(3,193)	(2,401,336)
Forest Conservation	(58,016)	(693)	(4,455,942)
Farmland Conservation	124,614	1,051	7,225,114

NY			
LandPolicyBMP	TN	TP	TSS
	-	-	-
Growth Management	(272)	(8)	(14,192)
Forest Conservation	(372)	2	(11,502)
Farmland Conservation	844	(67)	(88,202)

PA			
LandPolicyBMP	TN	TP	TSS
PA Custom (draft)	(158,146)	(943)	(1,080,715)
Growth Management	(144,057)	(2,282)	(2,773,207)
Forest Conservation	(71,604)	(286)	(1,938,386)
Farmland Conservation	294,538	505	4,676,093

VA			
LandPolicyBMP	TN	TP	TSS
VA Custom (draft)	(283,547)	(13,949)	(10,203,626)
Growth Management	(354,972)	(17,354)	(12,779,306)
Forest Conservation	(124,234)	(6,024)	(8,517,902)
Farmland Conservation	28,028	(12,568)	(4,317,837)

WV			
LandPolicyBMP	TN	TP	TSS
	-	-	-
Growth Management	(5,976)	(645)	(555,454)
Forest Conservation	13,601	(5)	(39,159)
Farmland Conservation	19,559	(890)	(235,193)

Overall Changes in Loads (all Jurisdictions).

LandPolicyBMP	TN	TN(%)*	TP	TP(%)*	TSS	TSS(%)*
Custom	(523,266)	-2.0%	(24,008)	-4.8%	(18,070,564)	-4.0%
Growth Management	(688,241)	-2.7%	(23,694)	-4.7%	(18,565,816)	-4.1%
Forest Conservation	(241,808)	-0.9%	(7,098)	-1.4%	(15,041,913)	-3.3%
Farmland Conservation	496,057	1.9%	(13,385)	-2.7%	7,296,809	1.6%

* percentages represent the percent of the total needed reductions from 2017 - 2025: 23.53M lbs TN; 0.5M lbs TP; and 450M lbs TSS

Growth management actions* minimize increases in development and septic pollution and the conversion of working and natural lands.

Table 3. Land Use Change By scenario (hectares)

Scenario	Impervious	Pervious	Natural	Agriculture	OpenSpace	Septic	Conversion Ratio**
Historic Trends (HT)	8,145	20,173	(14,667)	(14,760)	1,108	33,339	0.99
Current Zoning (CZ)	3,468	7,842	(6,428)	(5,360)	477	12,469	1.20
Growth Management (GM)	2,009	4,648	(3,620)	(3,328)	290	677	1.09
Forest Conservation (FC)	3,307	8,125	(4,685)	(7,336)	589	12,766	0.64
Agricultural Conservation (AC)	3,323	7,019	(8,869)	(1,617)	143	11,026	5.49

* Infill and redevelopment, expansion of sewer service, incentivizing growth in areas served by sewer, increasing the density of development (e.g., smaller lot sizes, townhomes, and condominiums).

** Conversion ratio = ratio of natural to agricultural land conversion

Claggett, et al., 2023.

Growth management actions* minimize increases in nitrogen, phosphorus, and sediment pollution

Table 5. Pollutant loads by scenario, 2013-2025 (kilograms)

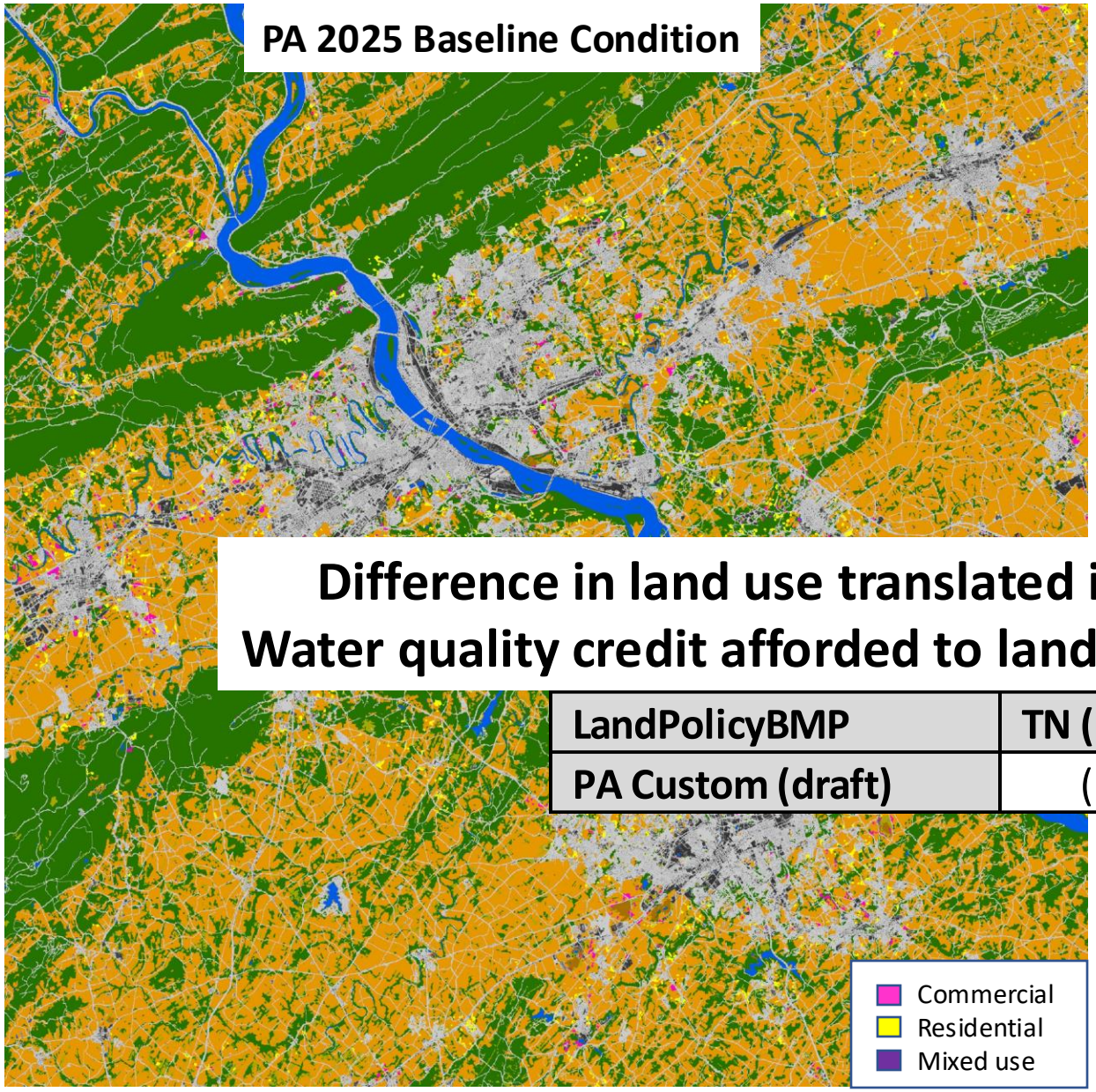
Scenario	Nitrogen	Phosphorus	Sediment
Historic Trends (HT)	445,190	35,132	104,674,328
Current Zoning (CZ)	178,664	15,061	46,223,641
Growth Management (GM)	6,508	8,427	26,017,014
Forest Conservation (FC)	127,119	12,361	37,030,104
Agricultural Conservation (AC)	256,755	17,783	53,741,402

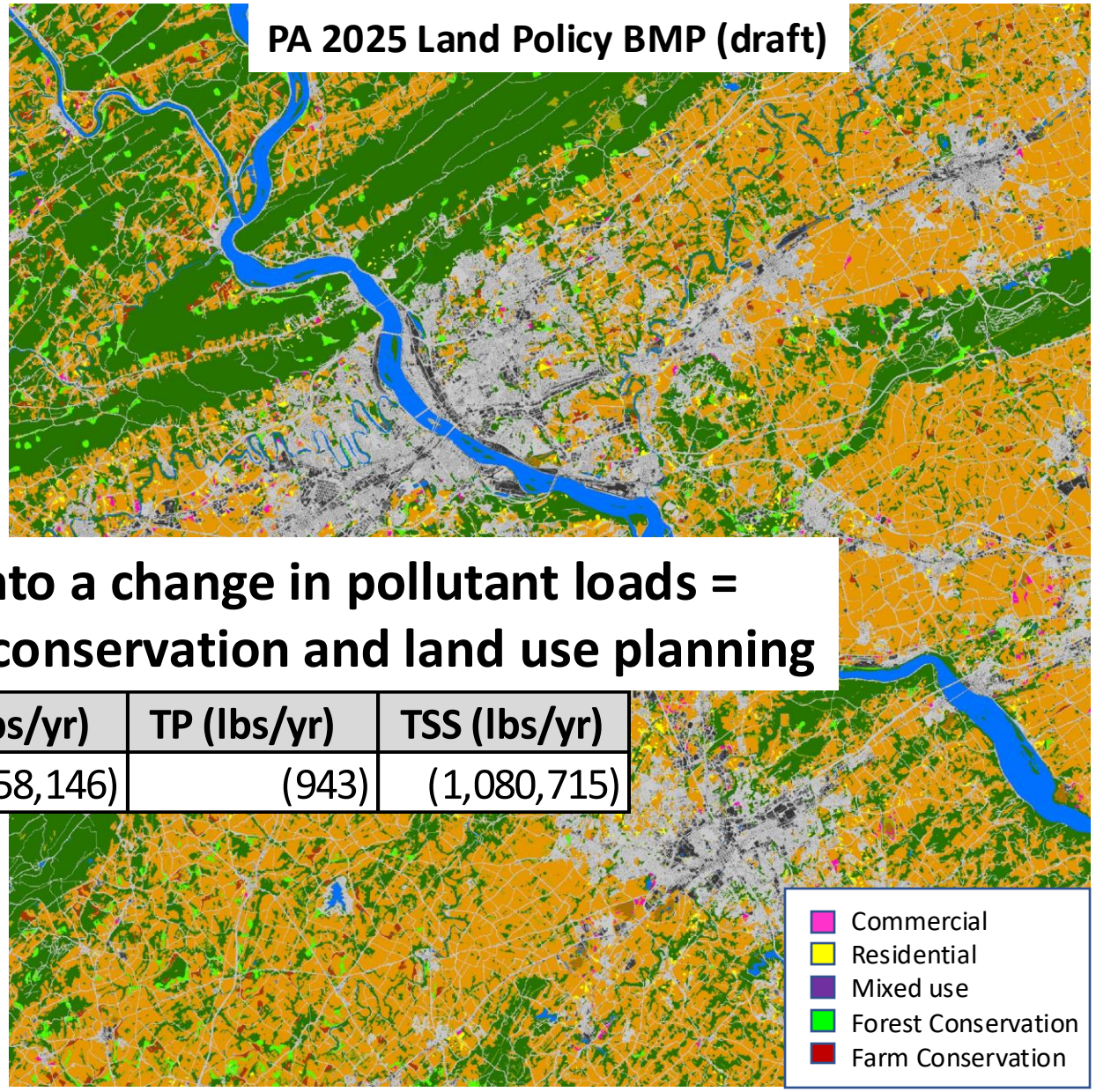
However: growth management does not ensure that the most valued forests and farmlands are protected from development. Therefore, growth management should be coupled with strategic land conservation.

* Infill and redevelopment, expansion of sewer service, incentivizing growth in areas served by sewer, increasing the density of development (e.g., smaller lot sizes, townhomes, and condominiums).

Claggett, et al., 2023.

Crediting Land Conservation and Planning towards Water Quality Improvement





Difference in land use translated into a change in pollutant loads = Water quality credit afforded to land conservation and land use planning

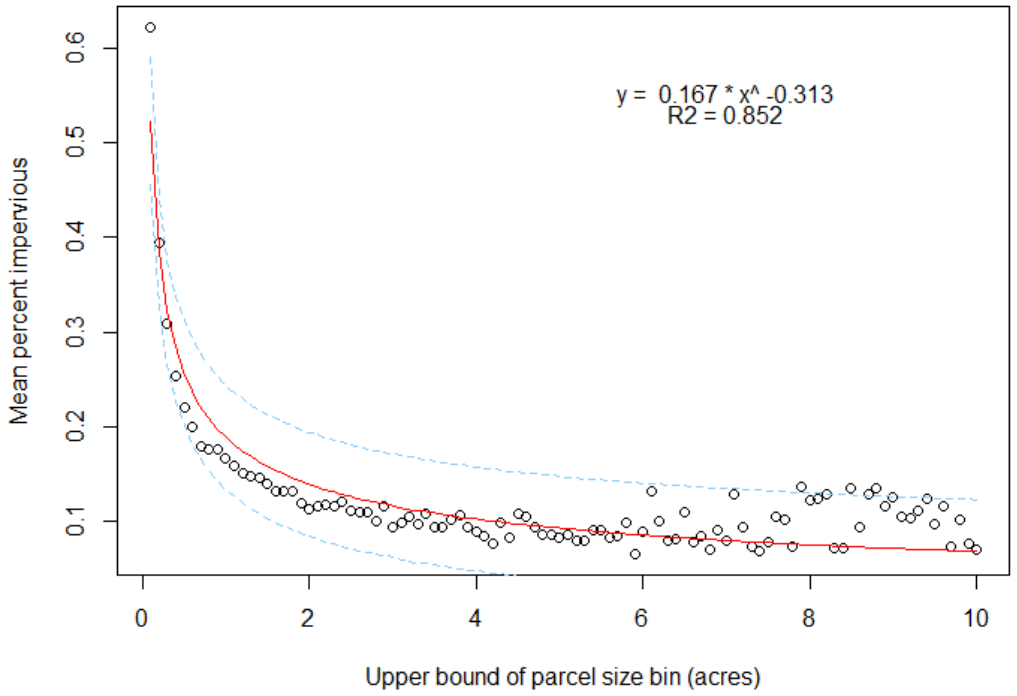
LandPolicyBMP	TN (lbs/yr)	TP (lbs/yr)	TSS (lbs/yr)
PA Custom (draft)	(158,146)	(943)	(1,080,715)

Estimating Impervious Area of New Development

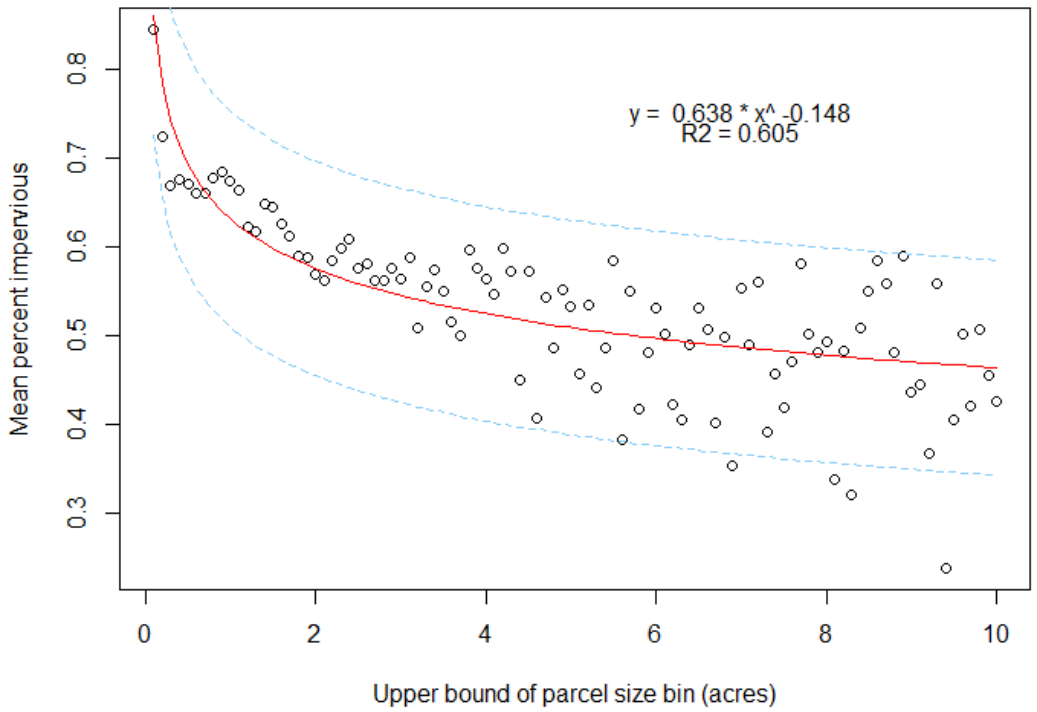
- State-specific
- Prediction of % Impervious given parcel size
- **Model inputs:** Residential and commercial parcels and high-res impervious cover

Impervious Coefficients for DE

Mean percent impervious by residential parcel size



Mean percent impervious by commercial parcel size



Residential and Commercial Area

<u>Ancillary inputs for tax parcel classification:</u>

- USPS Residential Delivery Codes
- High-resolution LULC
- Colleges, public and private schools
- Poultry houses
- Other land uses determined using ancillary data:
  - Cemeteries, landfills, golf courses, power infrastructure, convention centers, fairgrounds, mobile home parks, prisons, major sports venues, places of worship

Mix: Federally owned properties assigned to both residential and commercial class

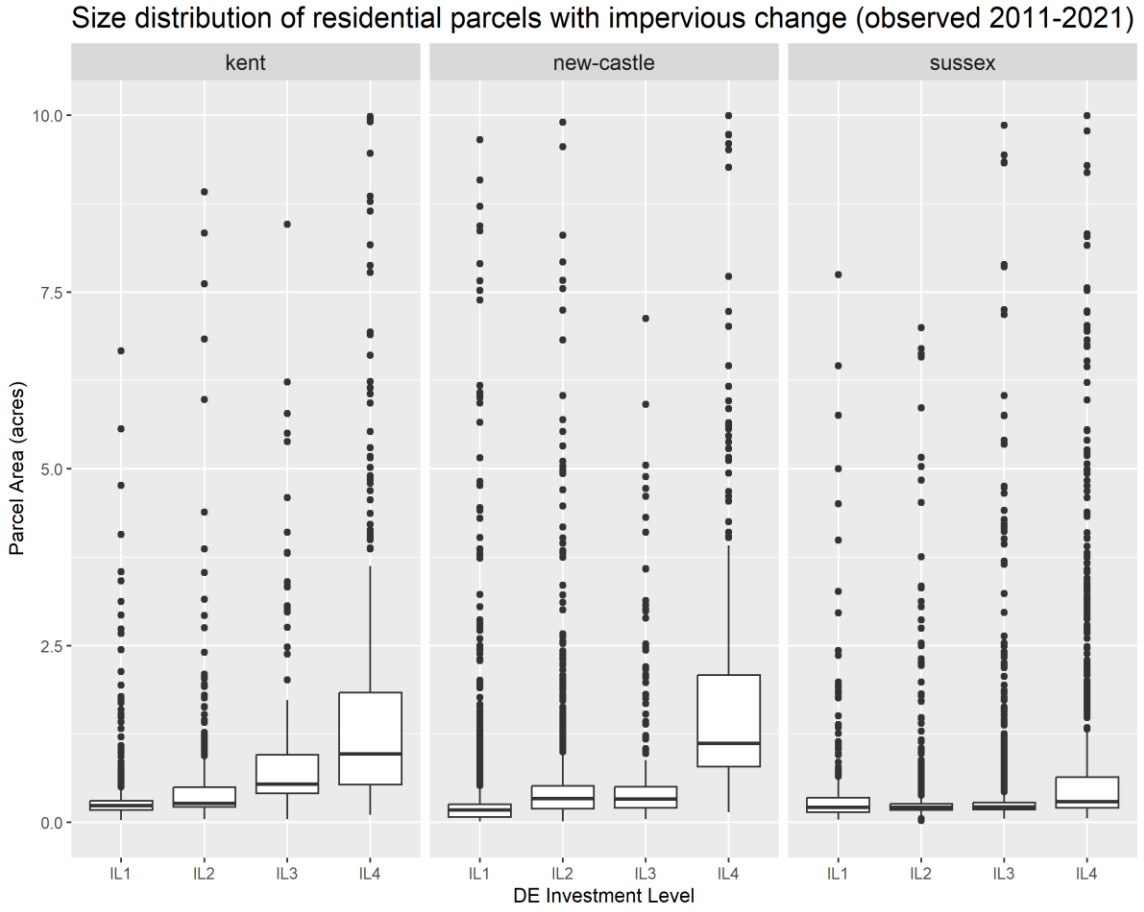
Density of new development

Mean values (left) compared to distribution of underlying data values (right).

Density of new development (observed 2011-2021)

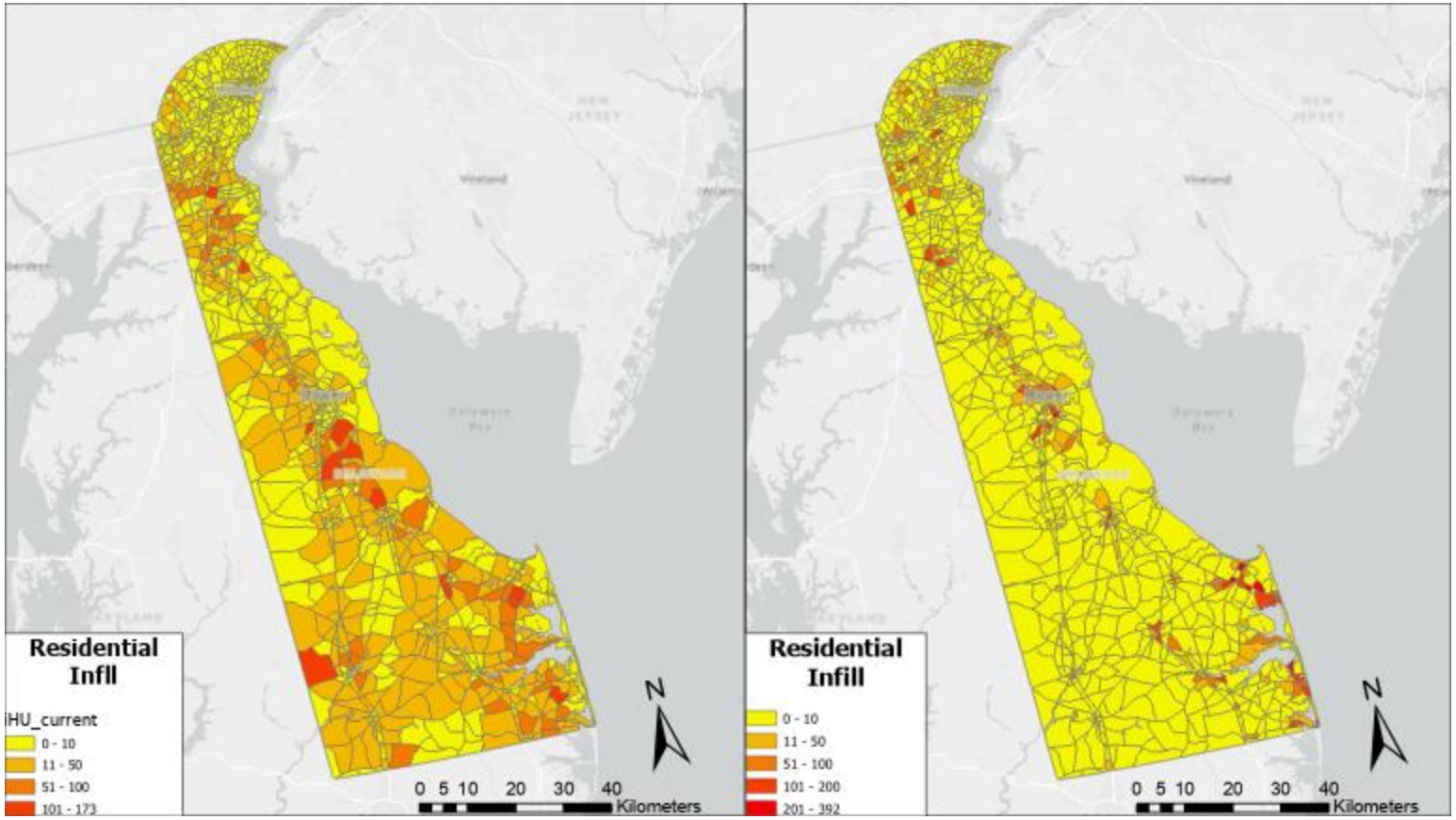
County	DE Zone	Mean Parcel Area (Acres)	St. Dev. Of Parcel Area
Kent	Investment Level 1	0.30	0.40
Kent	Investment Level 2	0.59	2.53
Kent	Investment Level 3	0.85	1.06
Kent	Investment Level 4	2.11	5.29
New-Castle	Investment Level 1	0.25	1.21
New-Castle	Investment Level 2	0.47	0.84
New-Castle	Investment Level 3	0.57	1.75
New-Castle	Investment Level 4	1.79	1.71
Sussex	Investment Level 1	0.51	2.33
Sussex	Investment Level 2	0.51	6.29
Sussex	Investment Level 3	0.57	3.71
Sussex	Investment Level 4	1.28	7.45

Sample size = 22,357 parcels



* Y-axis truncated to 10 acres

Infill/Redevelopment



Phase 6 CBLCM methods

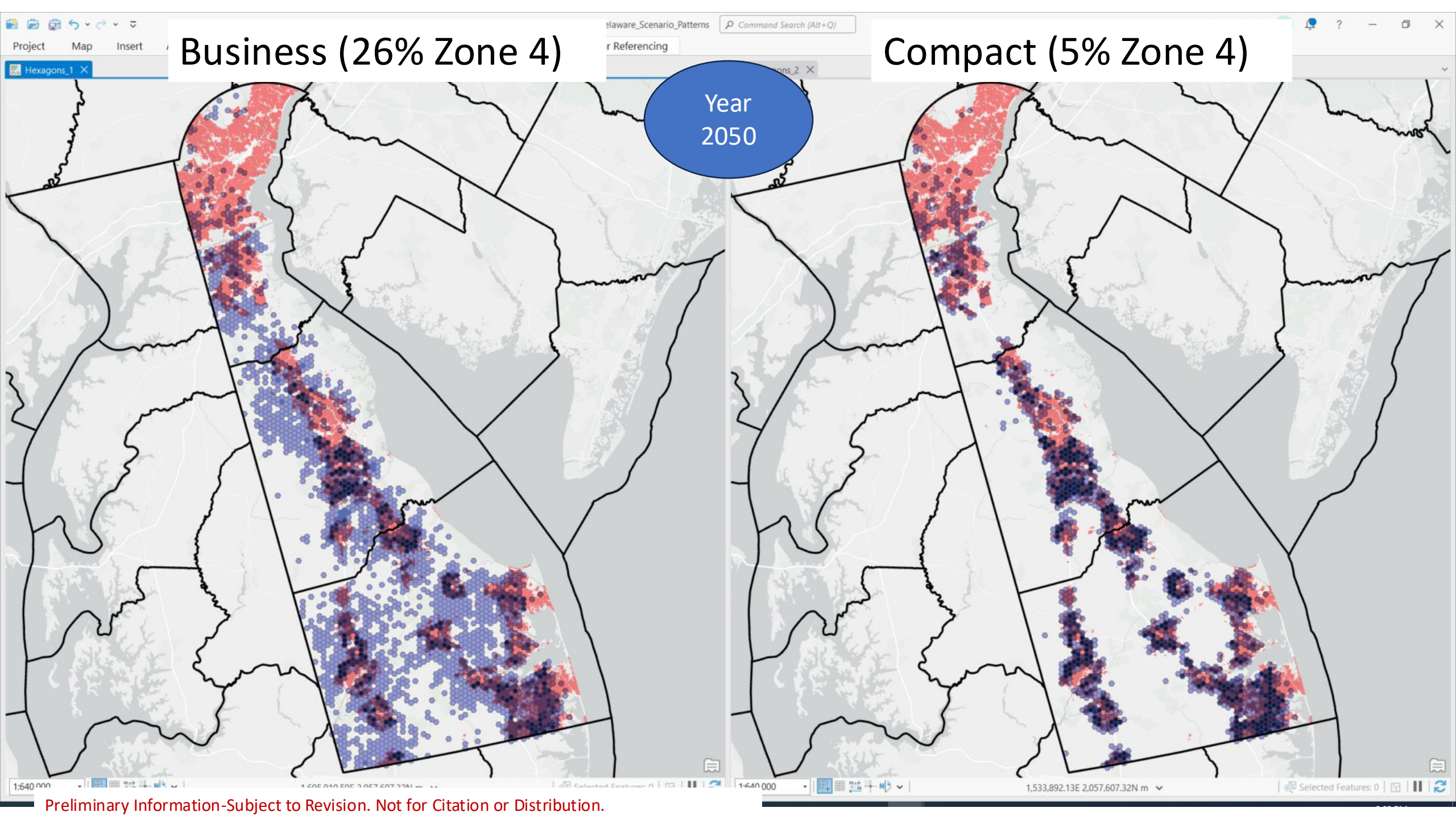
Update for Phase 7

Spatial residential infill by DE TAZ for 2020 historic trends scenario, calibrated over 2000-2010.

Business (26% Zone 4)

Compact (5% Zone 4)

Year
2050



Request for Feedback

- Value of Land Policy BMPs?
- Other applications/uses of future forecasts, e.g., vulnerability of forests to land conversion?

References

Claggett, Peter R., Ahmed, Labeeb, Irani, Frederick M., McDonald, Sarah and Thompson, Renee L. 2023. “ The Chesapeake Bay Land Change Model: Simulating Future Land Use Scenarios and Potential Impacts on Water Quality.” *JAWRA Journal of the American Water Resources Association* 00 (0): 1–26.