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INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN — ESTABLISHED BY ACT OF CONGRESS 1940

Projecting Stream Conditions Under Future Land Use and Climate Scenarios

21 April 2020

Urban Stormwater Workgroup Meeting

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and

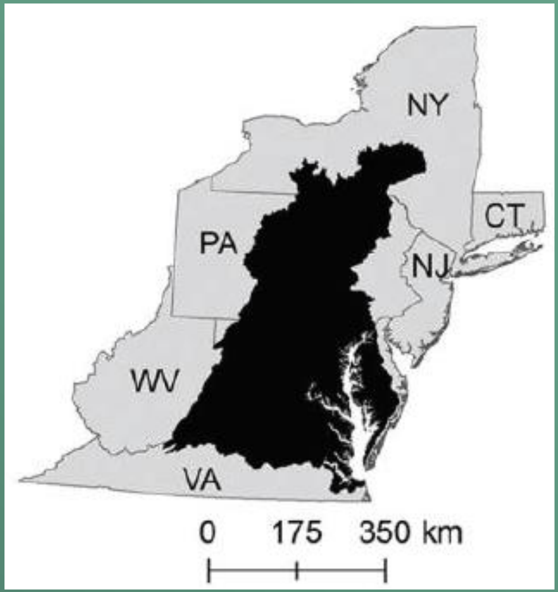
Claire Buchanan and Zachary Smith (ICPRB)

Collaborators

- **Zachary Smith and Claire Buchanan**, Interstate Commission on the Potomac River Basin (ICPRB), Rockville, MD
- **John Young and Kevin Krause** U.S. Geological Survey, Leetown Science Center, Aquatic Ecology Laboratory, Kearneysville, WV
- **Terry Sohl**, USGS Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD
- **Lauren Hay and Greg McCabe**, U.S. Geological Survey, Denver Federal Center, Denver CO.

Background

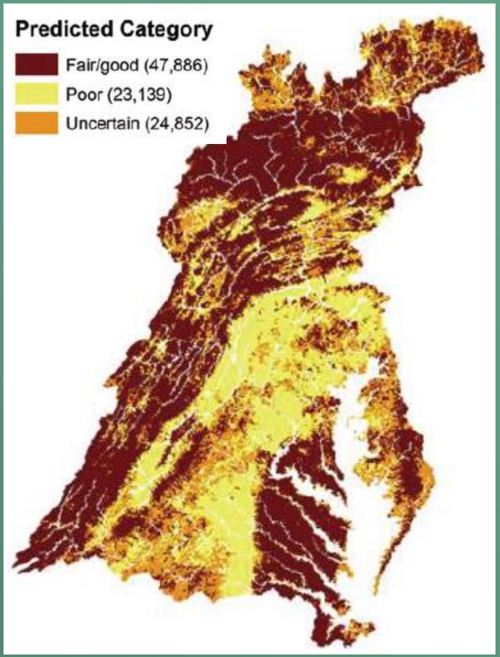
- Chesapeake Bay watershed drains into the largest estuary in the US.
- Over 18 million people reside in the watershed (2017).
- The watershed has a high level of development (11.0% in 2011) and agriculture cover (24.5%, NLCD).
- Restoration goal is to **improve** stream health and function for **10% of stream miles** above a 2008 baseline (Chesapeake Bay Program 2017).



Previous Baseline Estimates

Maloney et al. 2018:

- Bioregion – Family BIBI, 2004 – 2008 data,
- 63.6% catchments in Fair/Good condition,
- 49.9% with high certainty.



Buchanan et al. 2018:

- Bioregion – Family BIBI, 2006 – 2011 data,
- Composite of Maloney et al. modeled data and survey data,
- 60% of the basin's *area* had acceptable stream ratings (Excellent, Good, or Fair).

Challenge: How Could Land Cover and Climate Changes Affect Conditions?

- **Population** - predicted increase of 2 million by 2030.
- **Precipitation** - increased rainfall intensities and winter and spring precipitation levels (Dupigny-Giroux et al. 2018).
- **Temperature** - 2°C increase by 2035 over preindustrial era, the largest increase in contiguous US and two decades before global average (Dupigny-Giroux et al. 2018).
- **Temperature** - CMIP5 models estimate a 5.6°C increase from baseline 1971-2000 to 2071-2100 (Lynch et al. 2016).

Need to investigate how these may affect attaining and maintaining the 10% stream mileage improvement goal!

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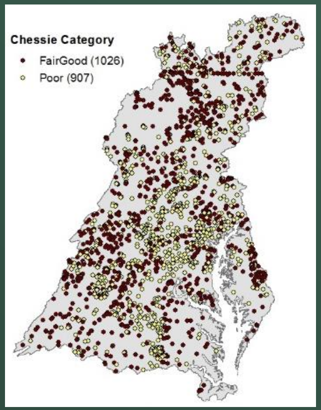
Objectives

1. **Build a predictive (Base 2005) model for stream integrity using the Chessie BIBI (2000-2011) and baseline stressor data.**
2. **Use this model to predict conditions for all unsurveyed streams in the watershed.**
3. **Forecast future stream conditions (2030, 2060, 2090) using future land use and climate scenarios.**

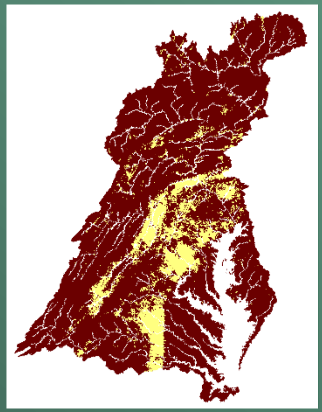
Today's Data



Today's Conditions

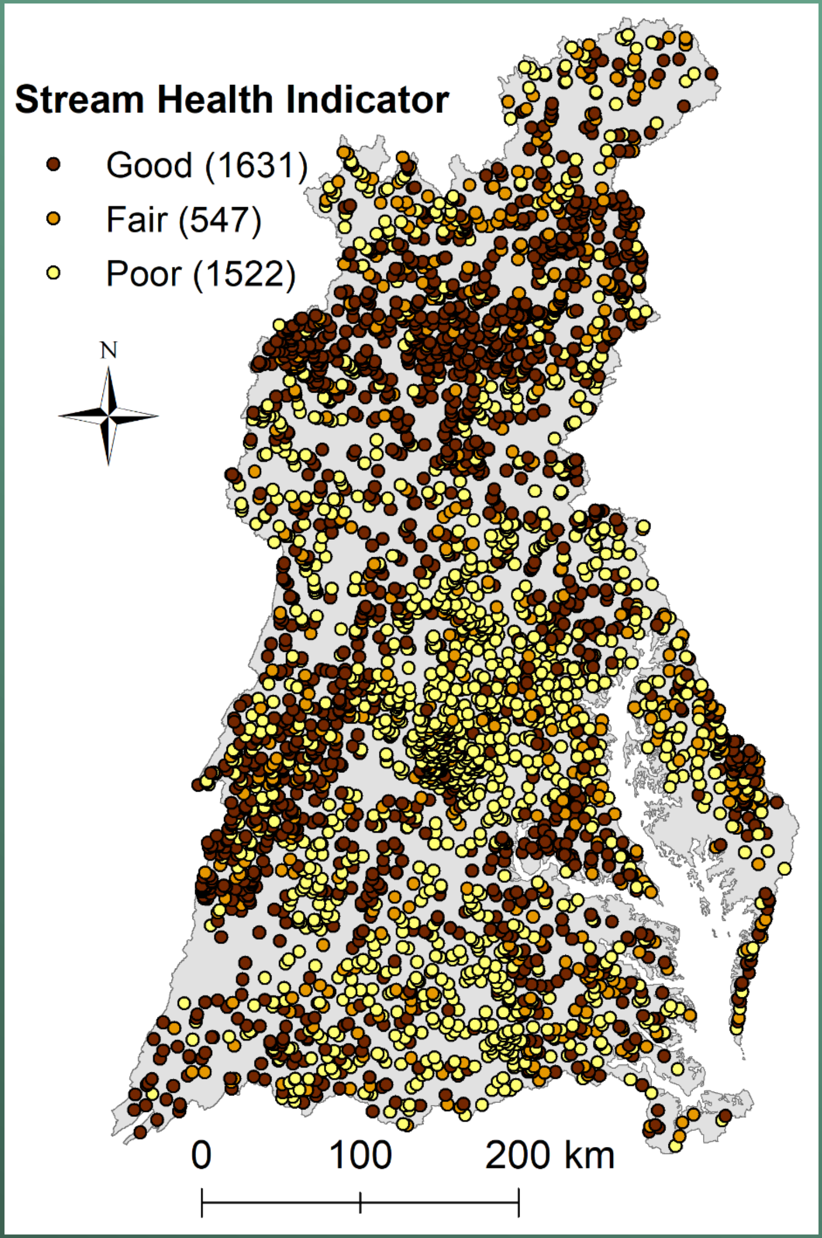
Predicted Conditions Time 1

Predicted Conditions Time 2



Building the Baseline Model

- January 01, 2000 to December 31, 2011 selected a baseline period.
- Used subset of independent, spatially adjusted Chessie BIBI samples.
- 3,700 stations – 44.1% in Good,14.8% in Fair and 41.1% in Poor Condition.



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Building the Baseline Model

- 75% (2775) of Chessie BIBI data used as training data and 25% (925) used as independent validation.
- Raw Chessie BIBI scores modeled as response.
- 36 upstream catchment landscape and stressor predictors characterizing bioregion, elevation, catchment area, soils, soil erodibility, lithology chemistry, base flow, runoff, seasonal total precipitation and average temperature (PRISM), land covers (n =12) and topographic wetness index.
- R package randomForest 4.6-14.
- 1,000 trees and mtry (# of variables randomly sampled as candidates at each split) set to 19 following tuning.

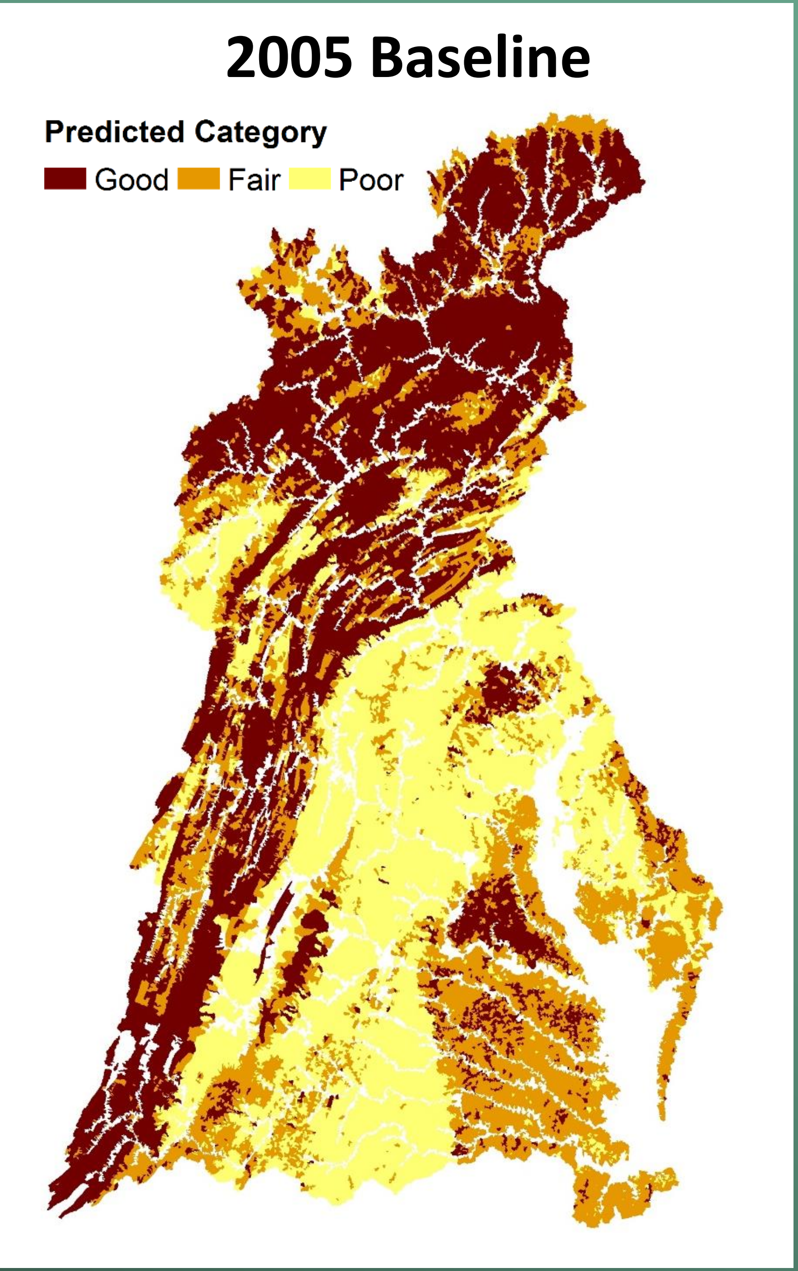
Model Results

- **Explained 36.1% of variation in Training data.**
- **In Test data 60.0% conditions classes correctly classified (76.1% Poor, 22.6% Fair, 74.8% Good).**

	Observed Test Data			
Predicted	Poor	Fair	Good	PCC
Poor	242	22	54	76.1
Fair	117	61	92	22.6
Good	39	46	252	74.8
			Total	60.0

Model Results - Watershed

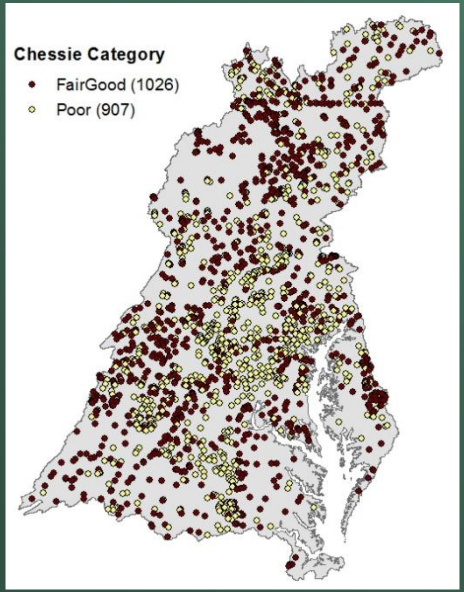
- **For baseline 2005 period:**
  - **33.5% Poor,**
  - **29.0% Fair,**
  - **37.5% Good.**



Forecasting

Use relationships in baseline model to predict future biological conditions based on alternative land use and climate scenarios.

Present Day Biological Data

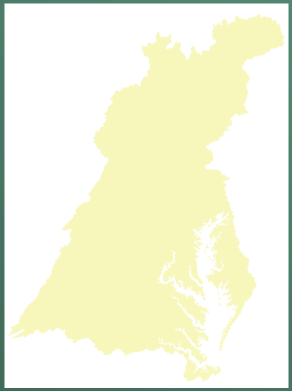


Present Day Stream Conditions

Future Stream Conditions

https://www.cnn.com/style/article/utopian-cities/index.html

OR



https://wallpaper.istriku.site/maze-runner-wallpaper-lock-screen/

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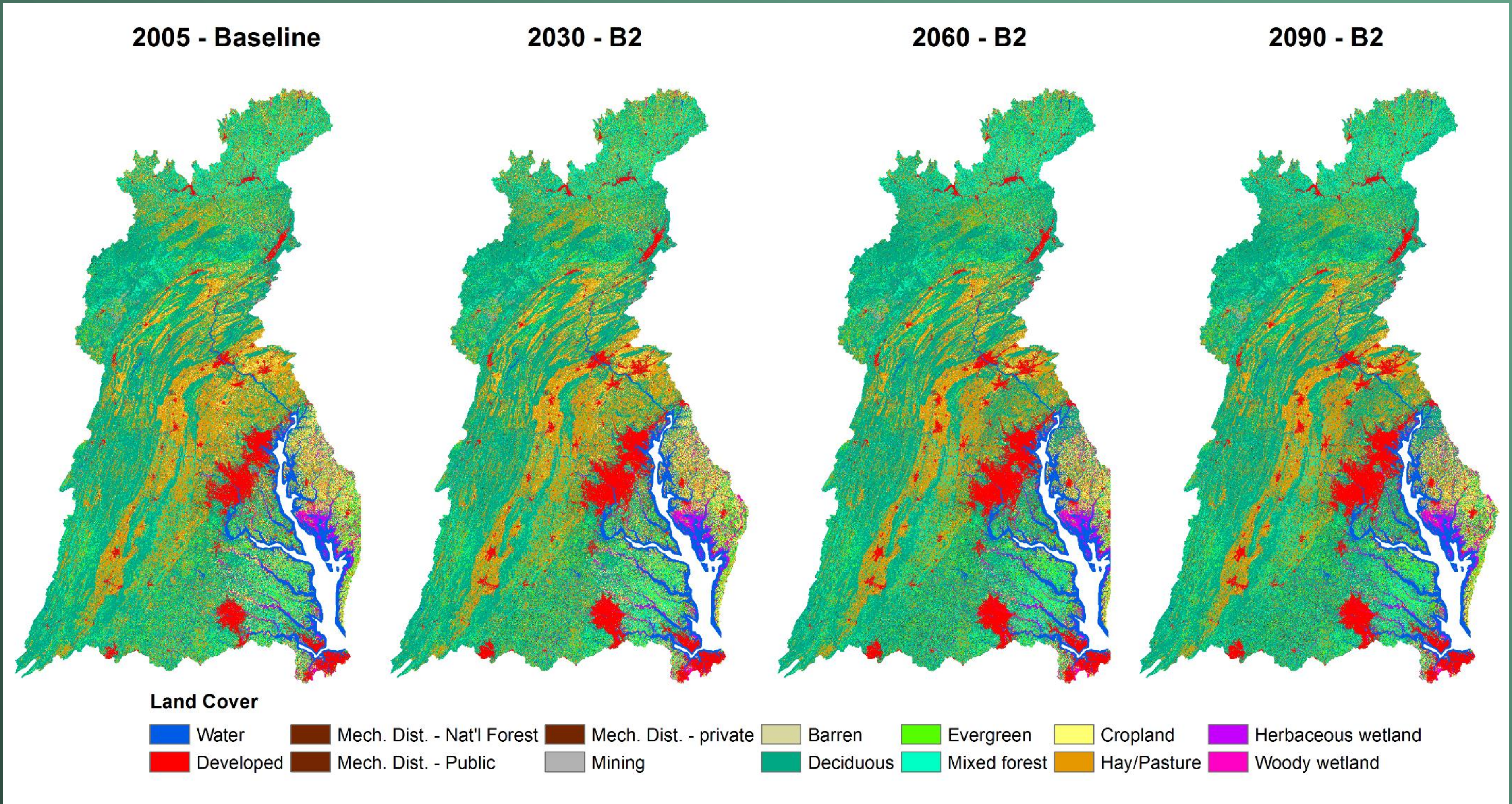
Forecasting Land Cover Scenarios

- **USGS EROS Land Cover Modeling** (https://landcover-modeling.cr.usgs.gov/projects.php).
- **Baseline conditions 1992-2005.**
- **Four scenarios – 2006-2100.**

	IPCC Special Report on Emissions Scenarios (SRES)			
	A1B	A2	B1	B2
Economic or environmental	Economic Growth	Economic Growth	Environmental Sustainability	Environmental Sustainability
Globalization / Regionalization	Global Convergence	Regional Development	Global Convergence	Regional Development
US Population	461 Million (2100)	628 Million (2100)	461 Million (2100)	366 Million (2100)
US Per Capita GDP	$146,807 (2100)	$67,536 (2100)	$92,086 (2100)	$87,616 (2100)
Energy Use	Very High: balanced sources	High: regionally sourced including fossil fuels	Low: transition to post-fossil fuel technology	Medium: regional, fossil fuel use declines over time
Technological Change	Rapid pace, rapid diffusion	Slow pace, slow diffusion	Medium pace, rapid diffusion	Medium pace, uneven diffusion
Resources and Land Use	Active management rather than conservation	Uneven, but weak environmental concern, focus on consumption	Sustainable development, efficient resource use	Uneven, with local solutions to environmental protection

Forecasting
Land Cover Scenarios



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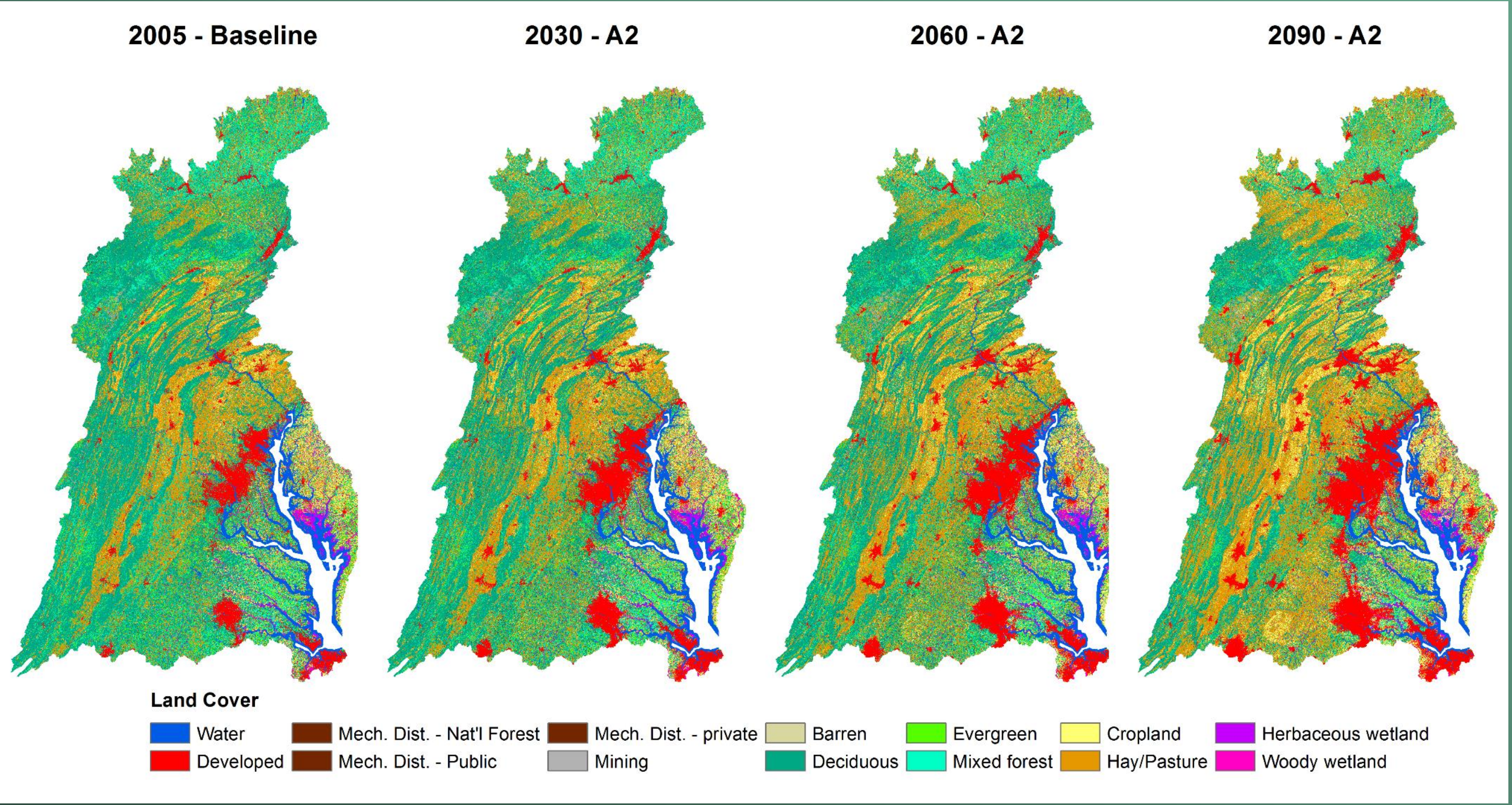
Forecasting
Land Cover Scenarios



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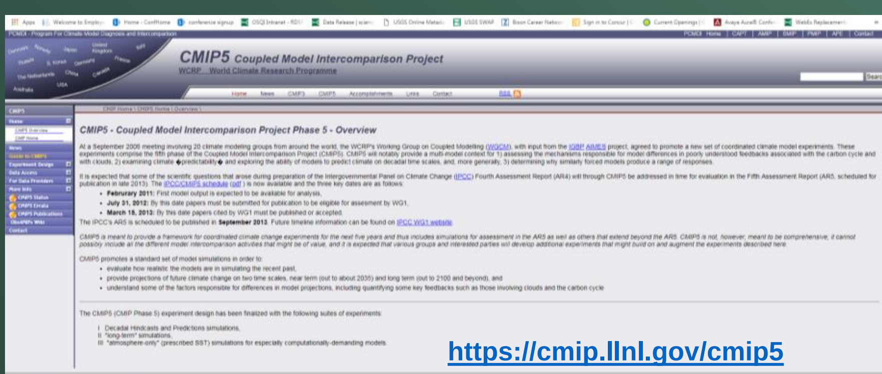
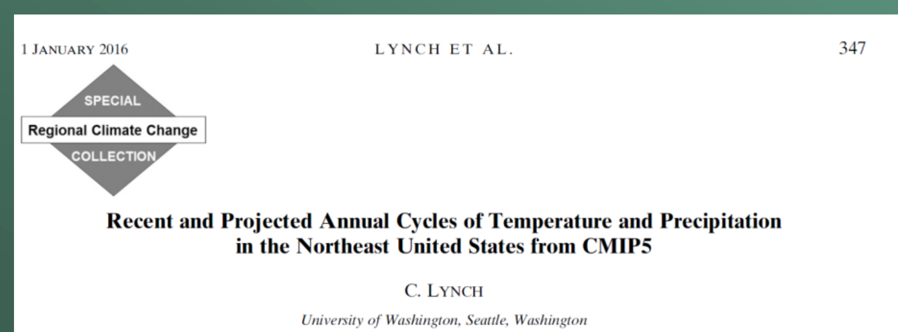
Forecasting
Climate Scenarios

- **Hay/McCabe:**
  - **CMIP5 - Coupled Model Intercomparison Project Phase 5, 122 different models.**
  - **Summarized differentials at 25th, 50th and 75th percentile.**
- **Lynch et al. 2016 – constant value.**
- **Added differentials to PRISM baseline data.**



https://cmip.llnl.gov/cmip5



1 JANUARY 2016 LYNCH ET AL. 347

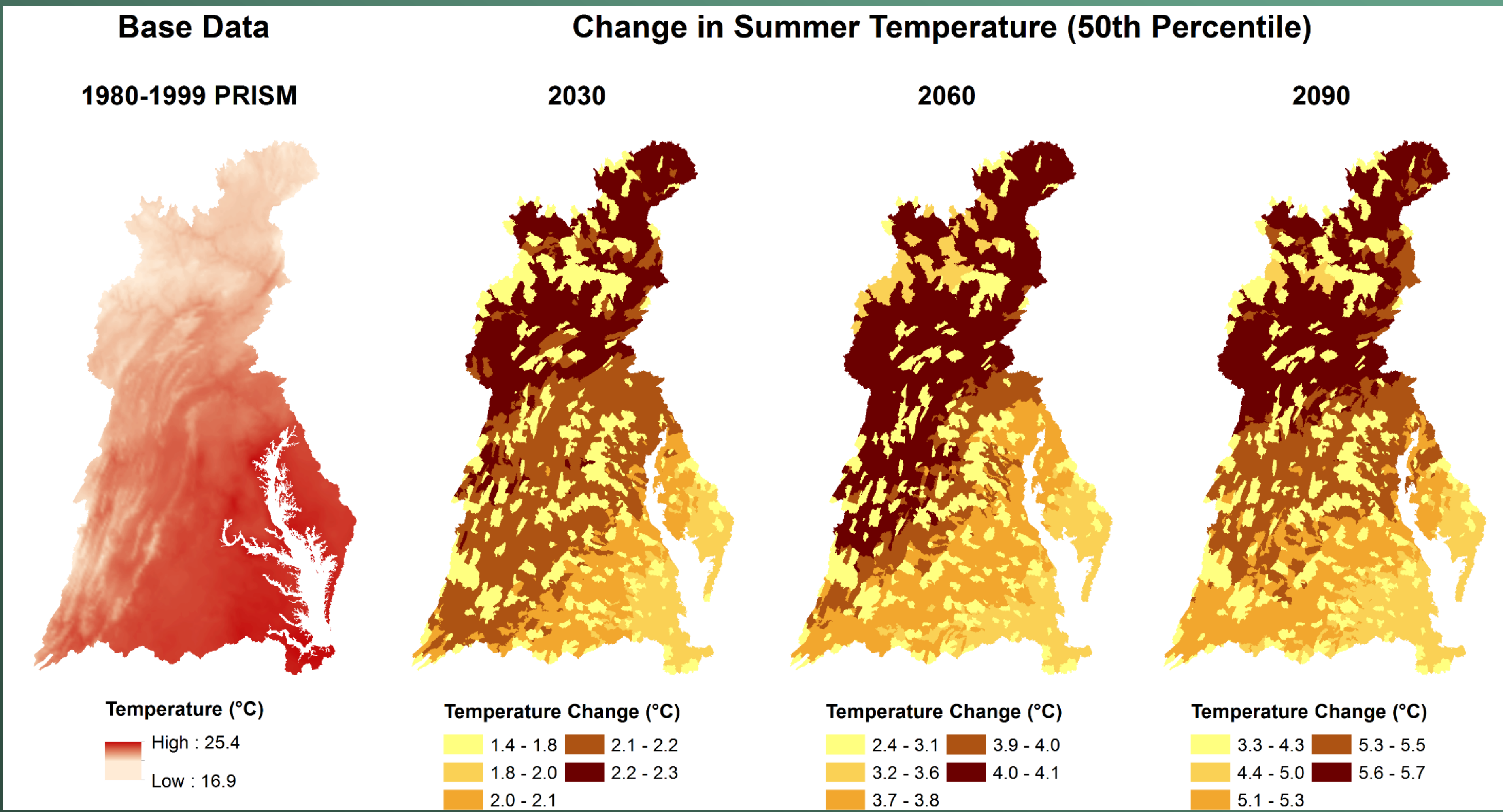
SPECIAL
Regional Climate Change
COLLECTION

Recent and Projected Annual Cycles of Temperature and Precipitation in the Northeast United States from CMIP5

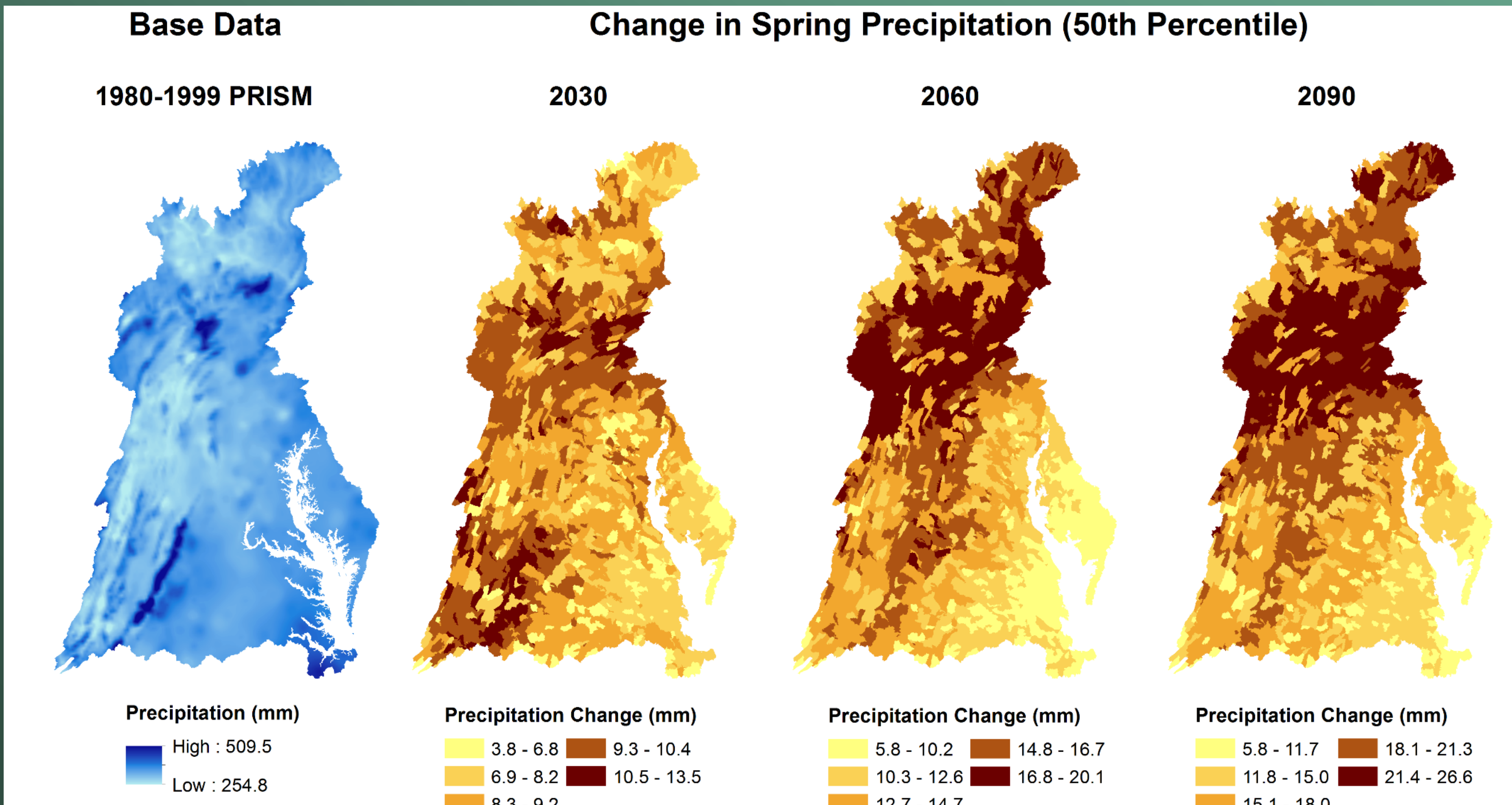
C. LYNCH

University of Washington, Seattle, Washington

Forecasting
CMIP5 Climate Scenarios - Temperature



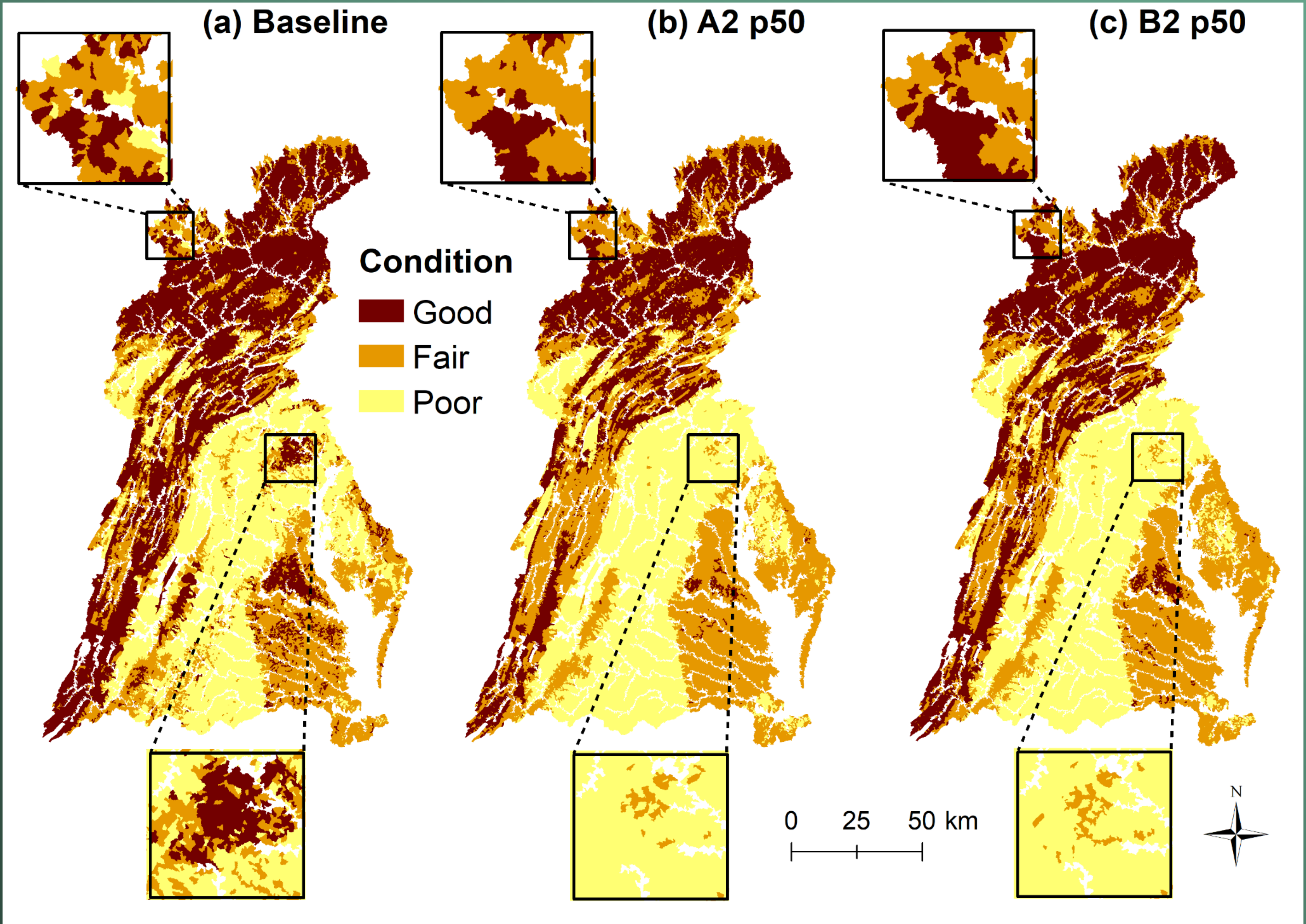
Forecasting
CMIP5 Climate Scenarios - Precipitation



Forecast Results

“It's tough to make predictions, especially about the future.”
— Yogi Berra

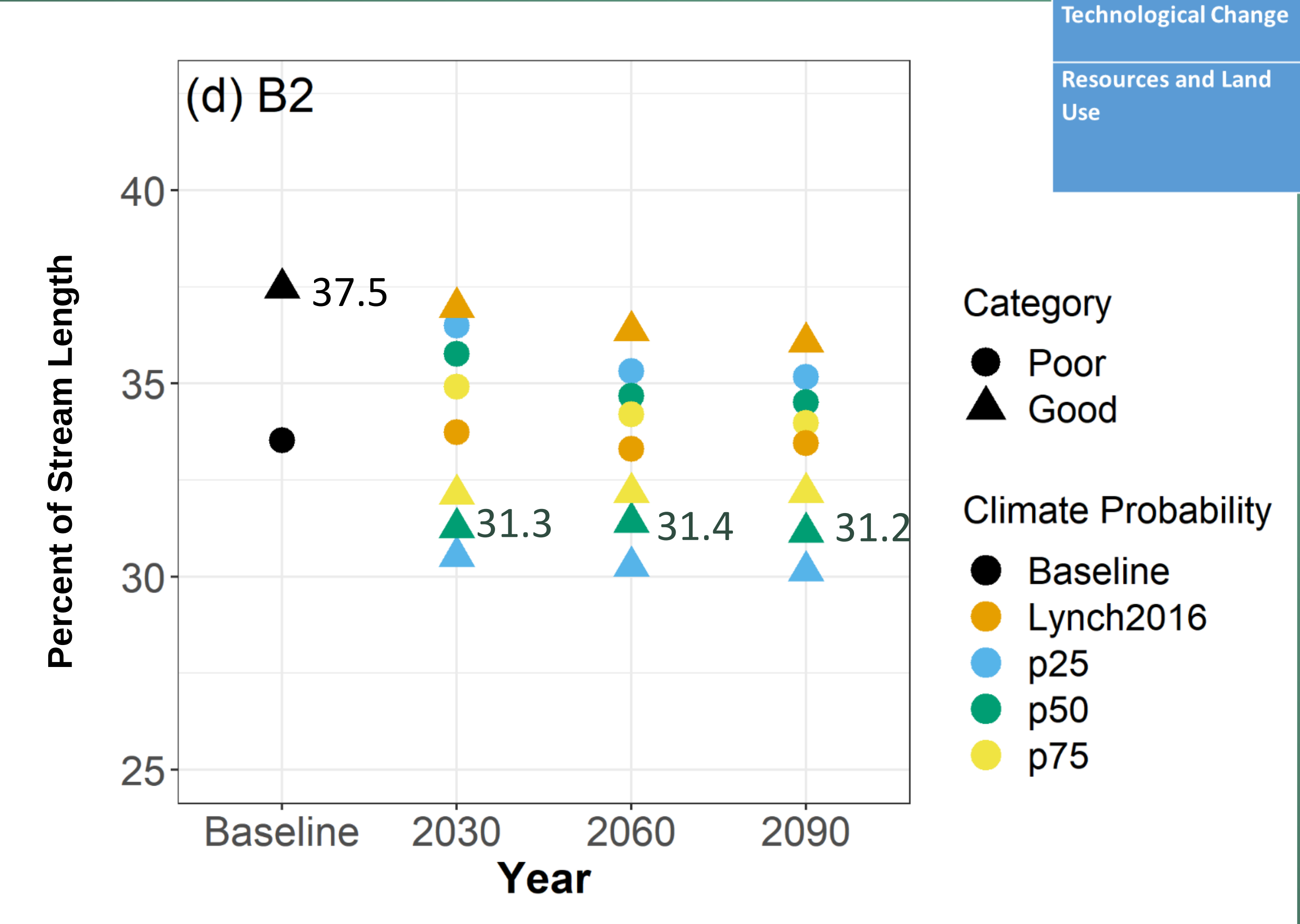
Forecast Results- 2090



Forecast Results

b2 land cover scenario with all climate scenarios.

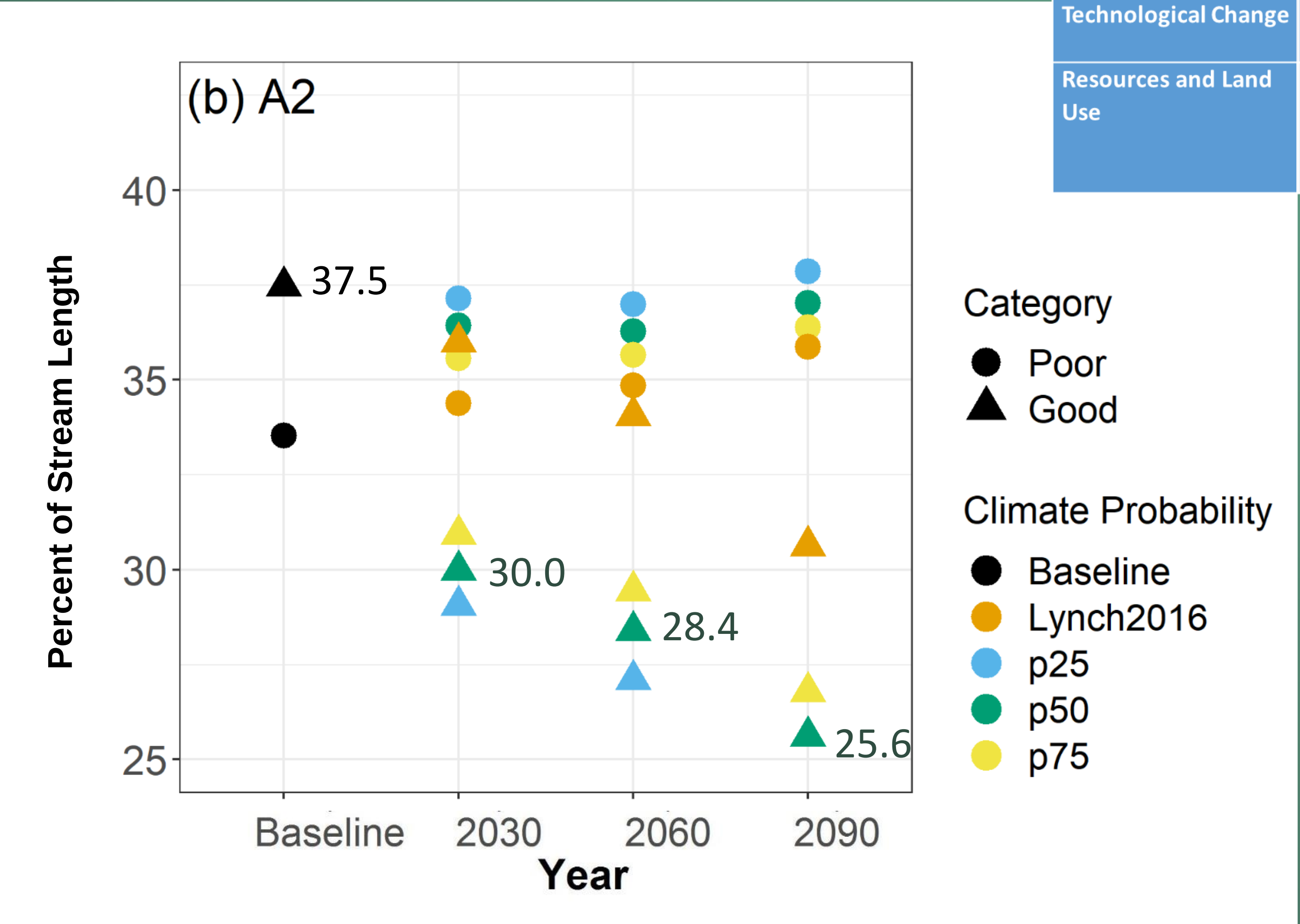
	B2
Economic or environmental	Environmental Sustainability
Globalization / Regionalization	Regional Development
US Population	366 Million (2100)
US Per Capita GDP	$87,616 (2100)
Energy Use	Medium: regional, fossil fuel use declines over time
Technological Change	Medium pace, uneven diffusion
Resources and Land Use	Uneven, with local solutions to environmental protection



Forecast Results

a2 land cover scenario with all climate scenarios.

	A2
Economic or environmental	Economic Growth
Globalization / Regionalization	Regional Development
US Population	628 Million (2100)
US Per Capita GDP	$67,536 (2100)
Energy Use	High: regionally sourced including fossil fuels
Technological Change	Slow pace, slow diffusion
Resources and Land Use	Uneven, but weak environmental concern, focus on consumption



How Could Land Use and Climate Change Affect the 10% Restoration Goal?

- With a Poor, Fair and Good classification system there are three ways to show improvement and decline:

- Improved: Poor to Fair, Poor to Good, Fair to Good.

- Declined: Good to Fair, Good to Poor, Fair to Poor.

- Need to quantify these changes.

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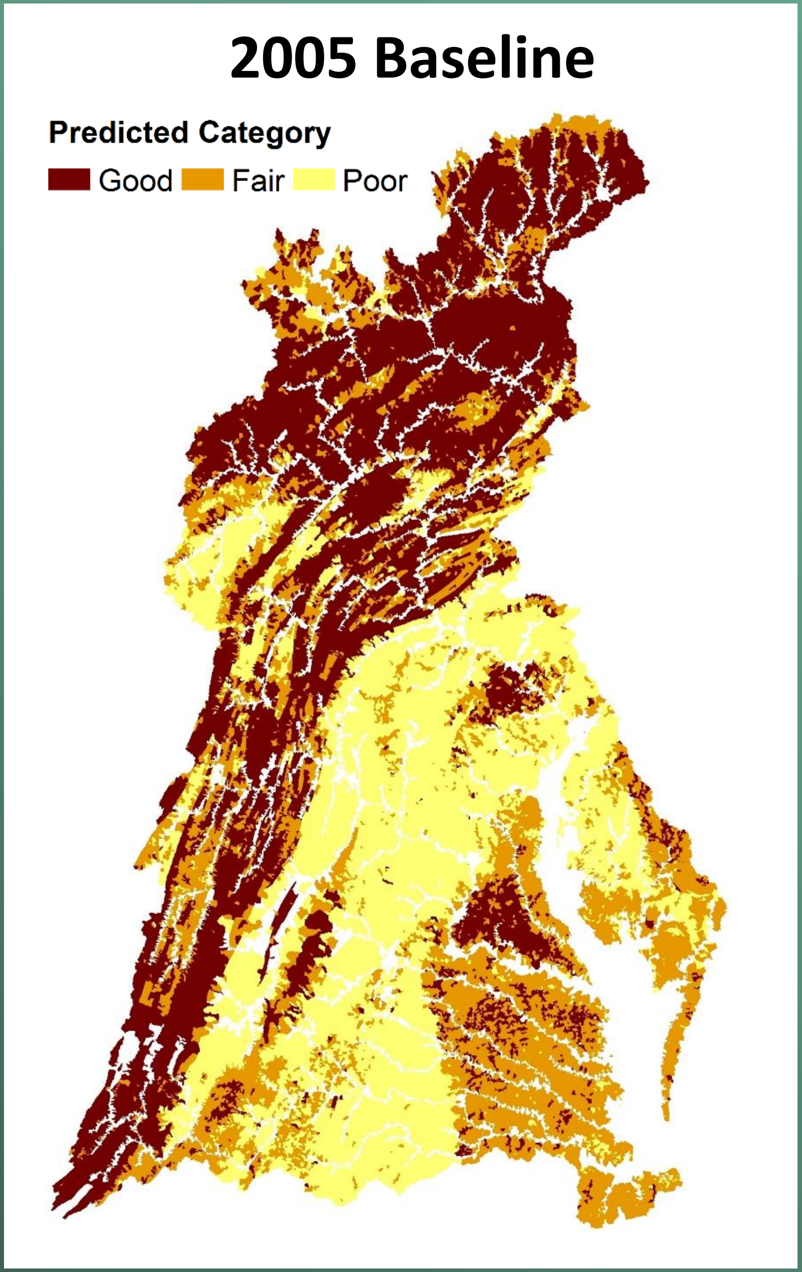
The 10% Goal

114,552 kms of streams in NHDPlusV2 (1:100,000).

2000-2010 baseline predicts Poor or Fair condition in 71,631 kms.

Thus, 7,163 kms need improvement to reach the 10% goal.



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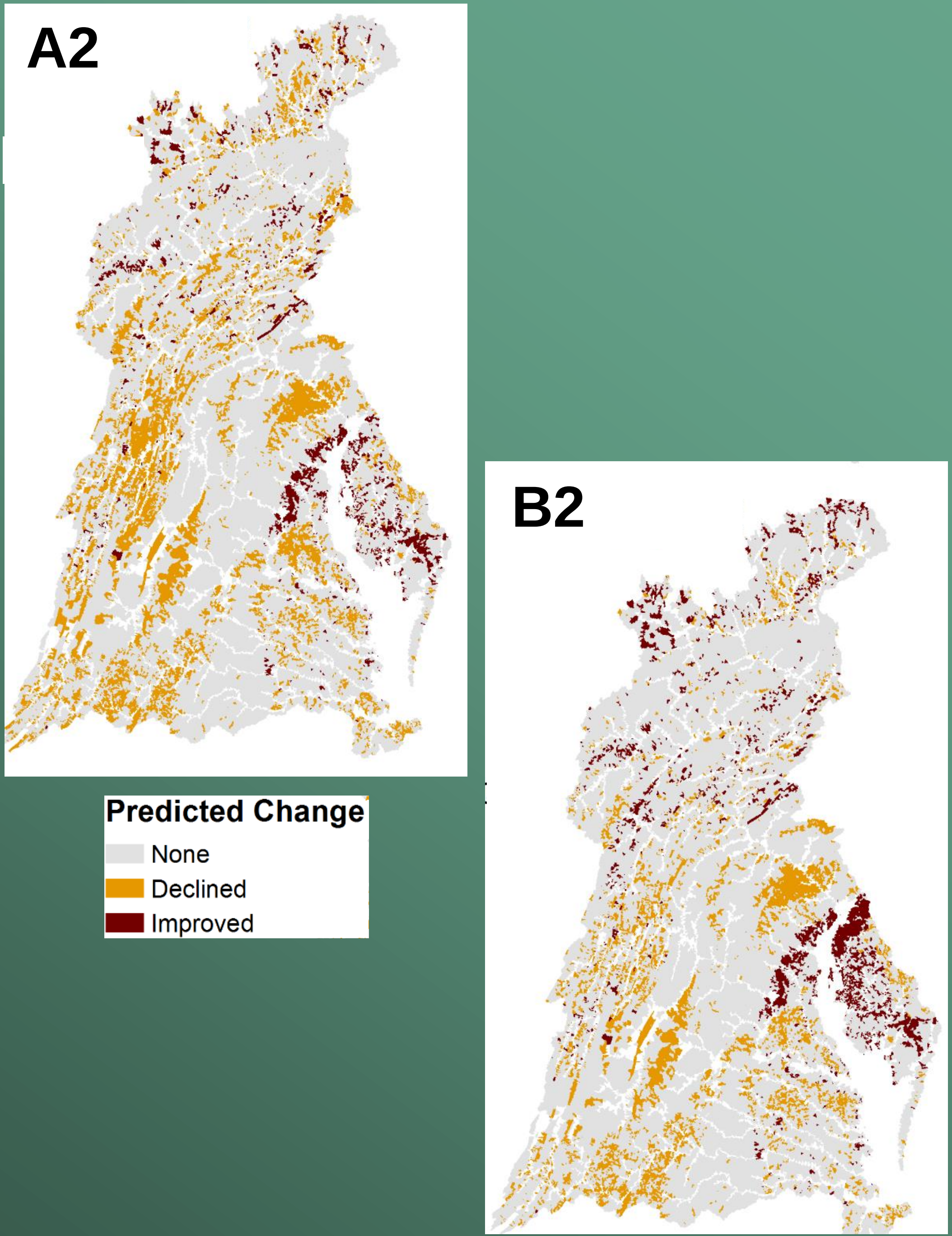
The 10% Goal

Forecasts; however, predicted a **decline** condition in **1.0-16.2%** of streams kilometers by 2090.

Thus to sustain the 10% 2025 goal requires improvements in between **11.0% – 26.2%** of stream kilometers.



Summary

- Combined Land use and P50 Climate scenario forecasts predict Good conditions will change:
  - –6.0% (b1) to –7.5% (a2) by 2030,
  - –6.1% (b2) to –9.1% (a2) by 2060,
  - –6.3% (b2) to –11.9% (a2) by 2090.
- To sustain the 10% restoration goal through 2090 may require improvements in 11.0 to 26.2% of stream kilometers.

Summary

- Combined Land use and P50 Climate scenario forecasts predict Good conditions will change:
  - –6.0% (b1) to –7.5% (a2) by 2030,
  - –6.1% (b2) to –9.1% (a2) by 2060,
  - –6.3% (b2) to –11.9% (a2) by 2090.
- To sustain the 10% restoration goal may require improvements in 11.0 to 26.2% of stream kilometers.
- Land use and climate scenarios are tools to explore uncertainty.

Ongoing Research and Next Steps

- Continue to refine the stream health modeling efforts.
    - Additional predictors,
    - Assist in refining IBI,
    - Examine assemblage components.
- Incorporate BMPs into modeling efforts.
- Update future projection with refined futures data.

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Ongoing Research and Next Steps

- Assessment of fish habitat for all reaches in the Chesapeake Bay watershed (1:100,000).
- Move to 1:24,000 base layer.
- Incorporate BMPs into modeling efforts.
- Project future fish habitat based on land use and climate scenarios.

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Acknowledgements

- **R: A Language and Environment for Statistical Computing**
- **Support was provided by the USGS Fisheries Program and the Chesapeake Bay Program.**
- **Andrea Nagel, ICPRB**

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- Anne Arundel County Maryland - Department of Public Works
- City of Baltimore - Department of Public Works
- Baltimore County Department of Environmental Protection
- District of Columbia Department of Energy and Environment
- Delaware Department of Natural Resources and Environmental Control
- Frederick County Department of Public Works
- Fairfax County Department of Public Works and Environmental Services
- Howard County Department of Public Works
- Loudoun County Department of Building and Development
- Montgomery County Department of Environmental Protection
- Maryland Department of Natural Resources
- New York Department of Environmental Conservation
- Pennsylvania Department of Environmental Protection
- Prince George's County Department of the Environment
- Susquehanna River Basin Commission
- United States Environmental Protection Agency
- USDA Forest Service
- United States Geological Survey
- Virginia Department of Environmental Quality
- Virginia Commonwealth University
- West Virginia Department of Environmental Protection

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Thank you!

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