Science Synthesis Preview: Impacts of Climate Change and Uncertainty on Watershed Processes, Pollutant Delivery, and BMP Performance

Presented by Emily Bock[1]

Steering Committee: Zach Easton[1], Ray Najjar[2], Julie Shortridge[1], Kurt Stephenson[3], Lisa Wainger[4]

[1]Biological Systems Engineering, Virginia Tech
[2]Meteorology and Atmospheric Sciences, Penn State
[3]Agriculture and Applied Economics, Virginia Tech
[4]Environmental Economics, UMCES

STAC-sponsored Science Synthesis Project for the CBP Partnership

- Purpose
- Research Questions
- Approach
- Continued Efforts
- Connecting to Decision-Making

Purpose

How may climate change impact on-going efforts to restore and protect the Chesapeake Bay?

Key Considerations

- How climate change uncertainties affect CBP's capacity to predict watershed responses and achieve desired outcomes
  - Change in BMP efficiency is acknowledged as an important factor but not currently addressed in ongoing (2019-2021) CBP Climate Change Analysis
- Opportunities for risk-based decision-making given future climate uncertainties
- Identify additional research needed to support robust landscape management

Research Questions

1. How do climate change and variability affect nutrient/sediment cycling in the watershed?
2. How do climate change and variability affect BMP performance?
   a. By what mechanisms can climate change and variability affect BMP nutrient and sediment removal efficiency?
   b. How does climate change uncertainty affect BMP performance variability?
3. Which BMPs will likely result in the best water quality outcomes under climate uncertainty?

Approach: a modified systematic review

- Balance
  - Addressing a broad topic, the need to be effective and efficient
  - Best practices to avoid bias and omission in literature/data selection
- Systematic review elements
  - Transparent, documented search plan
  - Define inclusion/exclusion criteria and extracted data
  - Critical appraisal of data quality
- Modifications
  - Adaptive/iterative search development, changes documented
  - Targeting of key resources recommended by steering committee, gray literature
  - Single database (Web of Science – most complete) and article screener

Approach: Q1 climate change impacts on nutrient/sediment cycling

- Targeted search
  - Contextualize current CBP approach to evaluating climate change impacts
  - Characterize climate modeling advancement in Bay watershed over last decade
- Systematic search
  - Observational and modeling studies in the Bay watershed that assess the impact of climate change and/or variability on nutrient and sediment cycling (transport, storage, speciation)
  - Core review of modeling studies predicting N, P, and/or sediment loads
  - Extracted data: geographical area, climate projections, watershed model, NPS loads
  - Supplemental studies of climate effects on relevant landscape processes, land use, or technological/methodological advances in predicting water quality impacts of climate

Approach: Q1 climate change impacts on nutrient/sediment cycling

- Analysis
  - Assess the relationships between change and uncertainty in observations/predictions of climate drivers and N, P, and sediment loading
  - Characterize output variability across all simulation studies as it relates to modeling approach to evaluate the relative uncertainty using qualitative or quantitative methods
- Preliminary findings
  - Since 2010 review of climate impacts on CB (Najjar et al.), at least 12 modeling studies of change in NPS pollution loading within Bay watershed in addition to CBP assessment
  - Dozens of recent studies on modeling advancement (e.g., GCM ensembles, higher certainty N deposition projections, sources of uncertainty)
  - Climate impacts on landscape processes, basis to infer NPS response

Approach: Q2 how climate change and variability affect BMP performance

- Targeted search
  - Current BMP efficiency assumed by CBP and extract accompanying quantitative or qualitative description performance variability/uncertainty
  - Describe implicit conceptual models of BMP types and identify environmental variables affecting BMP performance
- Systematic search
  - Part 1: Previous BMP reviews, extracting efficiency central tendency and range/variability, application details, factors influencing performance, in addition to CBP assessment
  - Part 2: BMP simulation studies under future climates, extracting model attributes and predicted change in efficiency
  - Supplemental studies as conceptual basis to infer BMP behavior under climate extremes

Approach: Q2 how climate change and variability affect BMP performance

- Analysis
  - Summarize BMP performance, conceptual model of controlling variables, knowledge gaps
  - Map climate change impacts on environmental variables onto BMP conceptual models
- Preliminary findings
  - BMP performance highly variable, known to be affected by design, site/environmental variables, and maintenance, the challenge is identifying dominant variables
  - Several high quality review papers (ag and urban) despite data limitations
  - In several climate change simulation studies, NPS loads predicted to increase while BMP performance to decrease at watershed scale, driven by increase in precipitation/runoff
  - BMP response differs in magnitude and even direction for different pollutants, seasonally

Approach: Q3 BMPs with the best outcomes under climate uncertainty

- Ideally, identify distribution of N, P, and sediment removal efficiency for specific BMPs, the relative importance of factors controlling performance, and overlay with climate uncertainty to predict effects on performance distributions
- Adaptive approach
  - Characterize mechanisms of climate impacts on BMP performance using mapped impact on relevant environmental variables from Q2
  - Aim to make statements about degree of certainty of impacts instead of probabilities
  - Categorizing BMPs by pollution removal mechanism to draw conclusions about related BMPs as strategy to overcome data limitations
  - Hypothesize/describe climate impacts on BMP performance with theoretical response functions

Continued Efforts

- Identifying further sources of relevant information
  - BMP studies under extreme events (storms, droughts, temperature extremes)
  - Observational studies of climate analogs for the Bay watershed
- Evaluate approaches to describe relative BMP performance uncertainty and sensitivity to climate impacts
  - Explore possible metrics of robustness
  - Assess strength and completeness of evidence
- Identify key knowledge gaps
  - What avenues of research might effectively address BMP and climate uncertainty?
  - What a modeling strategies would support a quantitative evaluation of the impact of these uncertainties?

Connect Synthesis Findings to CBP Decision-Making

- Research and communication framework inspired by Robust Decision-Making, an analytical process for decision making under deep uncertainty
- Identify BMP implementation/landscape management strategies that are effective across many possible climate futures
  - Which BMPs appear to the be most robust to climate change and BMP performance uncertainty? Which are the most sensitive?
- Characterize the vulnerabilities of these strategies (under what conditions do they fail?)
  - Which uncertainties dominate the CBP's ability to predict nutrient and sediment delivery to the Bay for a future climate?

Thank you

Emily Bock, Biological Systems Engineering, Virginia Tech, emilyml@vt.edu

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