

Chesapeake Bay BMP Climate Synthesis Report

# **Impacts of Climate Change & Uncertainty on Watershed Processes, Pollutant Delivery and BMP Performance**

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**Agriculture Workgroup**

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# Purpose

Evaluate Climate  
Change Impacts on  
Efforts to Restore  
& Protect the  
Chesapeake Bay

## Key Considerations

- Identity climate change effects on watershed processes & BMP performance
- Identify opportunities for improved decision-making given future climate uncertainties
- Identify additional research needed to support robust landscape management

# Primary Questions

*Modified  
Systematic  
Literature Review*

1. How does climate change affect nutrient/sediment cycling?
2. How does climate change uncertainty affect BMP performance?
3. Which BMPs will likely result in the best water quality outcomes under climate uncertainty?

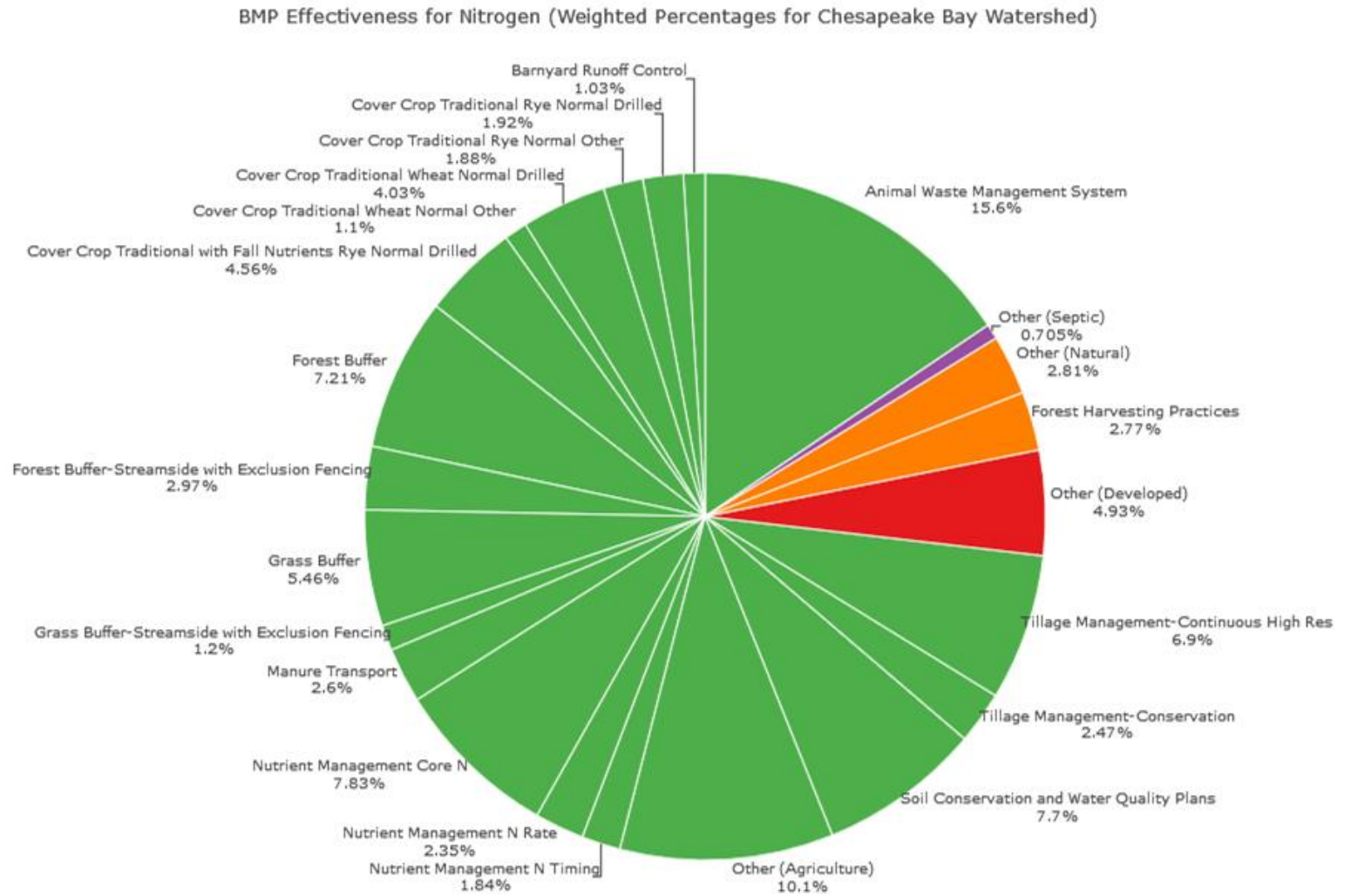
# 1. How does climate change affect nutrient/sediment cycling?

## **BMPs Will Have to Deal with Greater Fluxes & More Variability**

- Warmer, Wetter Winters & Springs
- Nitrogen Cycle Changes
  - Increased temp → increases in mineralization and nitrification, generally results in greater N yields
  - Increases in  $\text{NO}_3^-$  export due to substantial increases in nitrification (Temp effect) during the winter/spring and increased runoff (Precip effect)
- Phosphorus Cycle Changes
  - Slight to moderate increases Total P yield, a result largely of increases in sediment bound P during the winter/spring (Precip effect)
  - Warmer and wetter conditions, increase biomass utilization of dissolved-P, reducing P mineralization from fresh organic P.....consequently dissolved P levels change less (Temp effect)

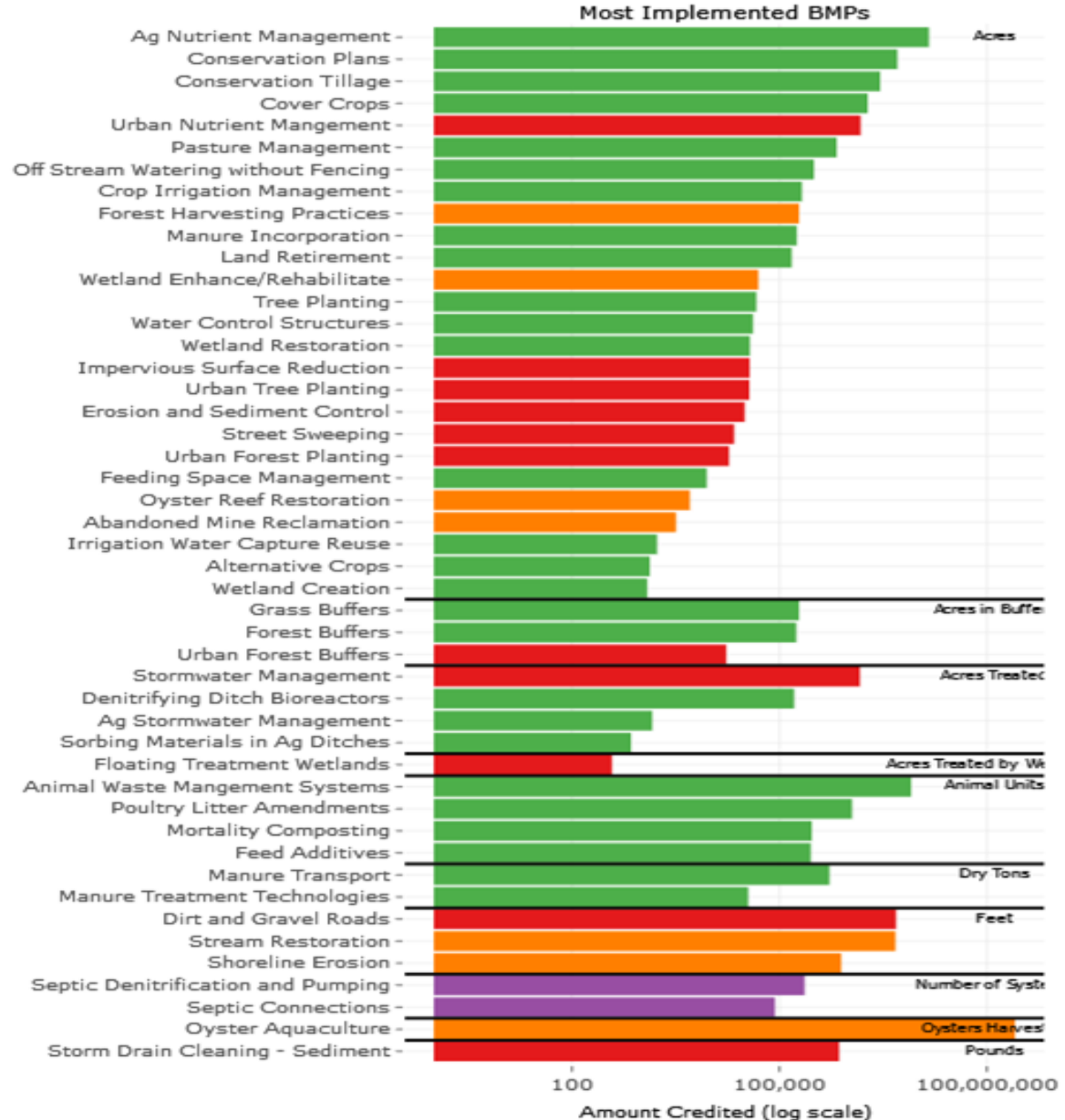
## 2. How does climate change affect BMP performance?

## Effectiveness of BMPs



## 2. How does climate change affect BMP performance?

### Implementation of BMPs



From CAST using jurisdictions' Phase 3 WIPs, accessed October 15, 2021 (<https://cast.chesapeakebay.net/Documentation/wipbmpcharts>); Chesapeake Bay Program, 2020. Chesapeake Assessment and Scenario Tool (CAST) Version 2019.

## 2. How does climate change affect BMP performance?

Most implemented	NOAA
<u>By units planned</u> <u>implementation/treatment</u>	
Ag Nutrient Management	Living shoreline
Tillage Management	Tidal wetland restoration
Cover Crops	Oyster restoration
Urban Nutrient Management	Oyster aquaculture
Pasture Management	stream restoration
Forest Harvesting	
Manure Incorporation	
Land Retirement	
Wetland Rehabilitation	
Tree Planting	
Wetland Restoration	
Grass Buffers	
Forest Buffers	
Animal Waste Management Systems (AWMS)	

Lit Review:  
Climate Change Related Studies

### Key

Zero studies

Few studies, may include some high-quality reviews

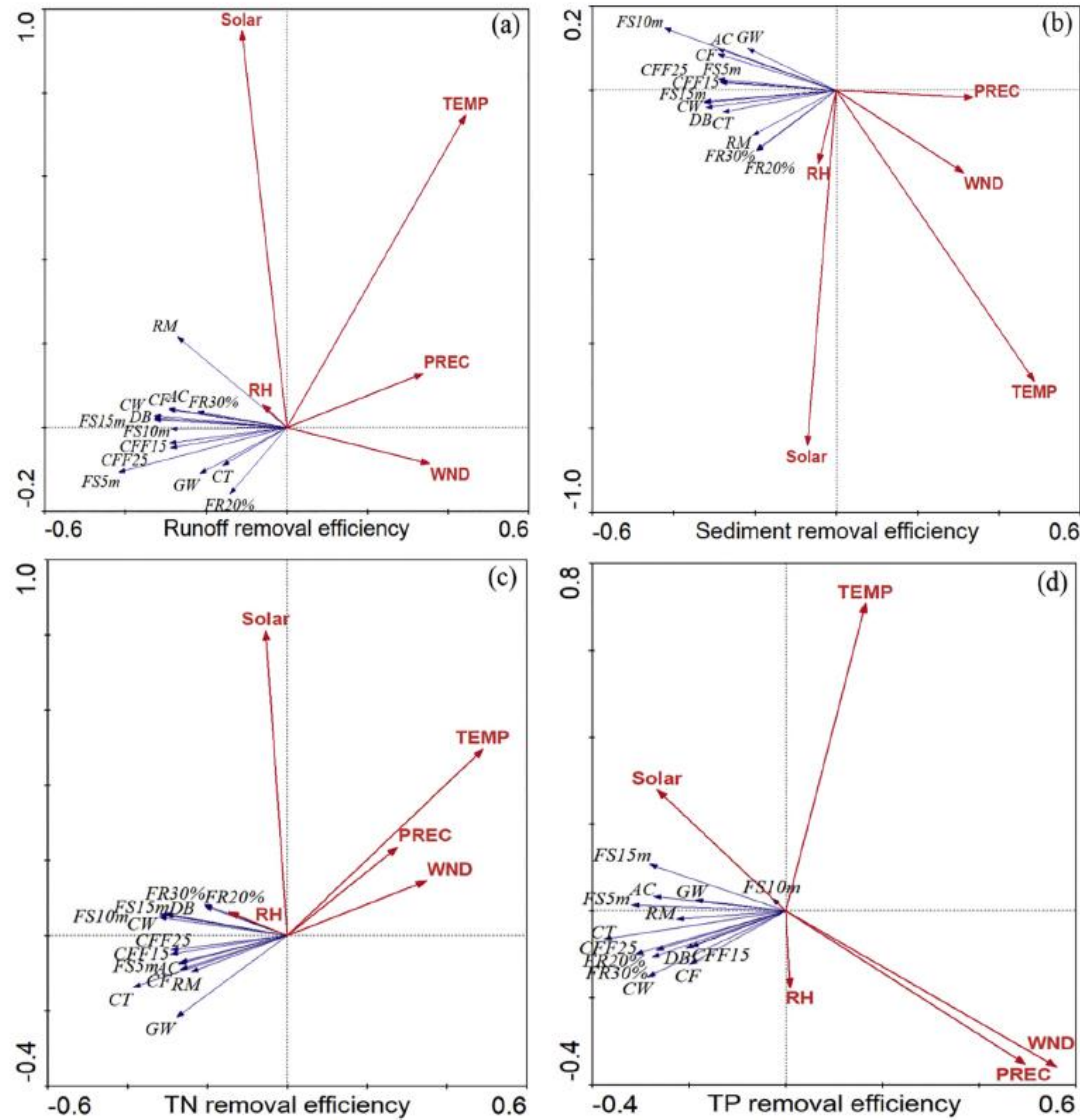
Several studies or high quality

### Other BMPs discussed in the reviewed lit:

veg. buffers or filter strips;  
drainage water management;  
bioretention



## 2. How does climate change affect BMP performance?



## Future Climate Factors & (modeled) BMP Performance

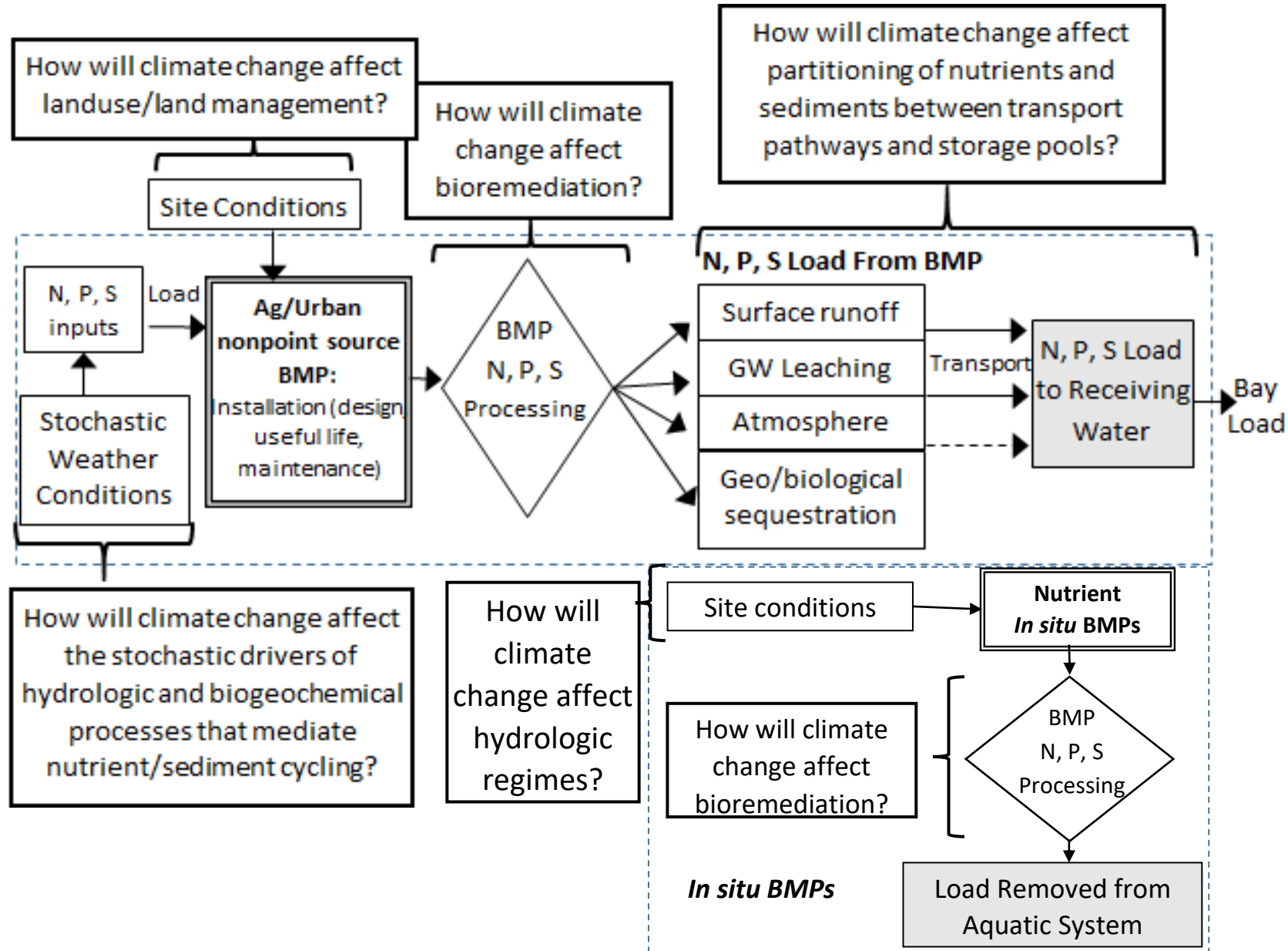
***Emerging area of research...***

*Need strengthened understanding  
of causal impacts of climate*

Fig. 5. Relationships between annual runoff (a), sediment (b), TN (c), and TP (d) removal efficiencies of 14 BMPs with climate factors, including precipitation (PREC), temperature (TEMP), solar radiation (Solar), relative humidity (RH), and wind speed (WND), during 2020–2099. Abbreviations of BMPs are given in Table 1.



## 2. How does climate change uncertainty affect BMP performance?



### Conceptual Framework

*How the BMPs remove, transform, or otherwise reduce nutrients & sediment loads*

- Refined scale with adequate information (e.g., field/empirical studies)

OR

- Higher level understanding of gaps & research priorities
- Can be used with other conceptual models

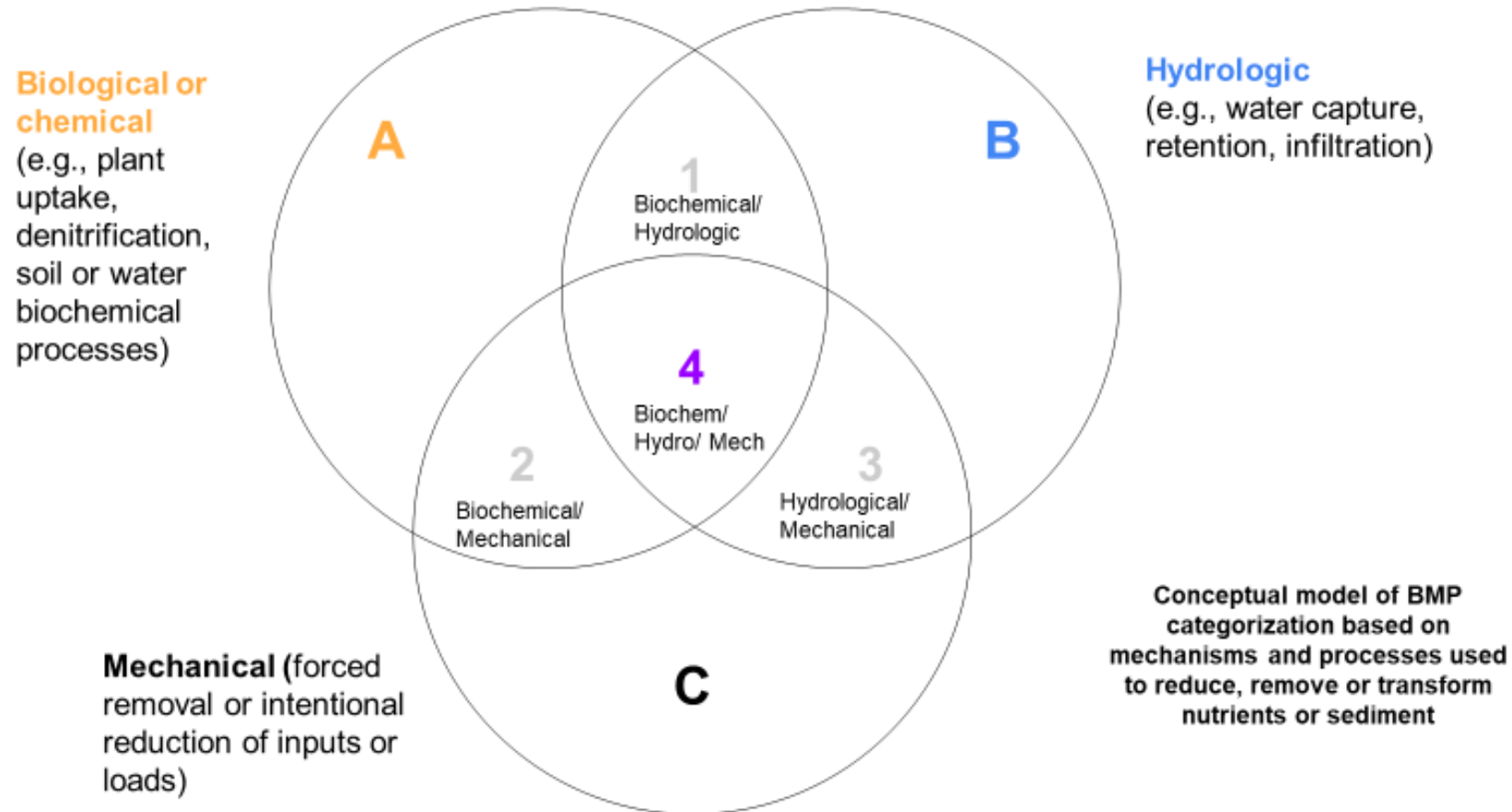
## **BMPs Will Have to Deal with Greater Fluxes & More Variability**

### **2. How does climate change affect BMP performance?**

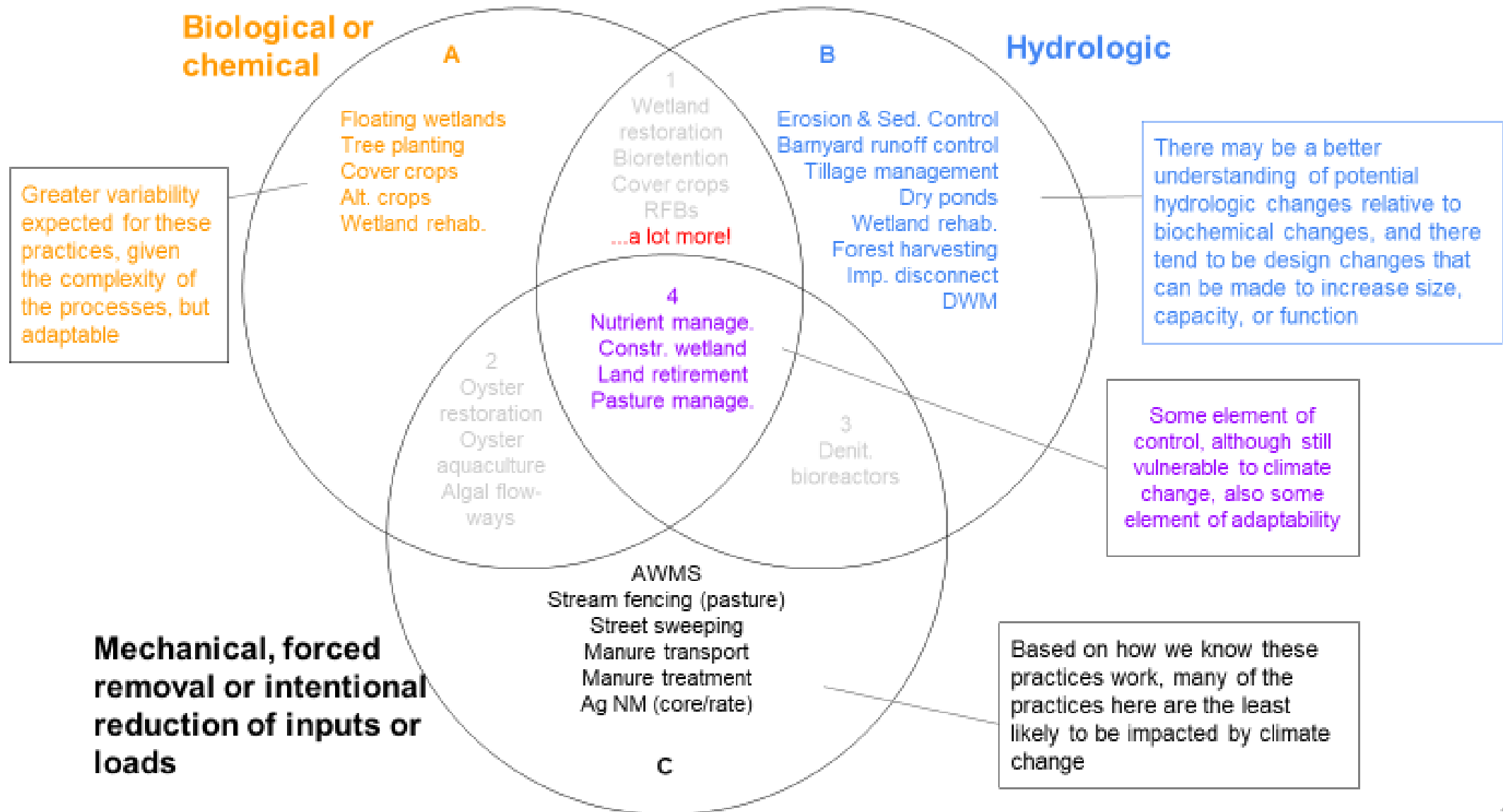
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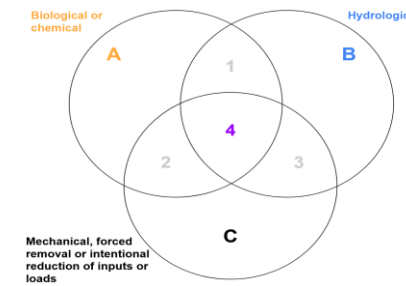
## BMP Classification Scheme



# BMP Classification Scheme



# Applying BMP Classification Scheme



BMP or BMP group	Class	Performance depends on	Relevant Climate Factors	Expected risks under future climate	Possible intervention
Cover Crops	1 or A	Crop species or mixture; planting date and method; establishment	Precipitation variability/intensity; altered growing season; Increased temps and CO <sub>2</sub>	Diminishing performance from increased variability, but countered by increased plant biomass from CO <sub>2</sub> effect <sup>1</sup>	Continued research to improve species selection, timing, planting recommendations
Wetland Rehabilitation	A or B (or 1)	Landscape position; design; complex factors, time	Precipitation variability/intensity; Increased temps and CO <sub>2</sub>	Diminishing performance from increased water balance but countered by increased plant biomass from CO <sub>2</sub> effect <sup>1</sup>	Monitoring; inspect and maintain, update designs and recommendations, develop more adapted species
Tree Planting	A	Planting density and survival; upkeep or maintenance	Precipitation variability/intensity; altered growing season; Increased temps and CO <sub>2</sub>	Diminishing performance from increased variability but countered by increased plant biomass from CO <sub>2</sub> effect <sup>1</sup>	Monitoring; develop more adapted rapidly maturing species

<sup>1</sup> Although evidence exists that many of these natural type BMPs may function better under higher temperatures and CO<sub>2</sub> concentrations as long as moisture and nutrients are not limiting (this also depends on plant type, C3 or C4 species).

## Preliminary Findings or Conclusions

# *Impacts of climate change watershed processes*

- Precipitation & temperature increase
- Streamflow overall increase, more in winter, less in summer
- Nitrogen yields largely mimics streamflow (increases), but also changes to N cycling rates
- Phosphorus yields increase due to increased sediment bound P (more than dissolved P)



Preliminary Findings or  
Conclusions

*Impacts of  
climate change*

*BMP  
performance*

**Lack of comprehensive or detailed  
understanding of individual BMP functioning  
(even most-studied/most-reviewed BMPs)**

Why? → many factors including...

- inconsistent reporting of key data in empirical studies
- reliance on models to evaluate BMP performance under future climates
- lack of information about management factors (maintenance, failure, skill/knowledge)

## Preliminary Findings or Conclusions

# *Implications of climate change*

**Average BMP contribution is *usually* net removal for desired pollutant under future climate**

- *But* some BMPs range from net negative to positive removal under current conditions (can be pollutant source or pollutant sink)
- No conclusive evidence that any BMP will be rendered ineffective, on average, under future climate conditions
  - more research needed (knowledge gap)
  - maintenance & verification remain vital; unclear if human or management factors outweigh climate change

**We can conceptualize BMP “performance resilience” without comprehensive information**

- For example: redundancy, complimentary mechanisms or practices

# Knowledge Gaps (abridged- part 1)

## **Needed: More long-term studies of BMPs**

- especially for BMPs that are particularly complex or are vulnerable to climate change

## **Gap: Literature rarely describes maintenance or upkeep of long-term practices**

- almost never considers BMP failure

## **Needed: Studies on non-linear responses of system to climate variability/change & interaction with other anthropogenic stressors**

# Knowledge Gaps (abridged- part 2)

**Modeling studies of BMPs under future conditions - by necessity - do not account for drivers of significant landscape changes impacting BMPs (population growth, land use change, other socioeconomic factors)**

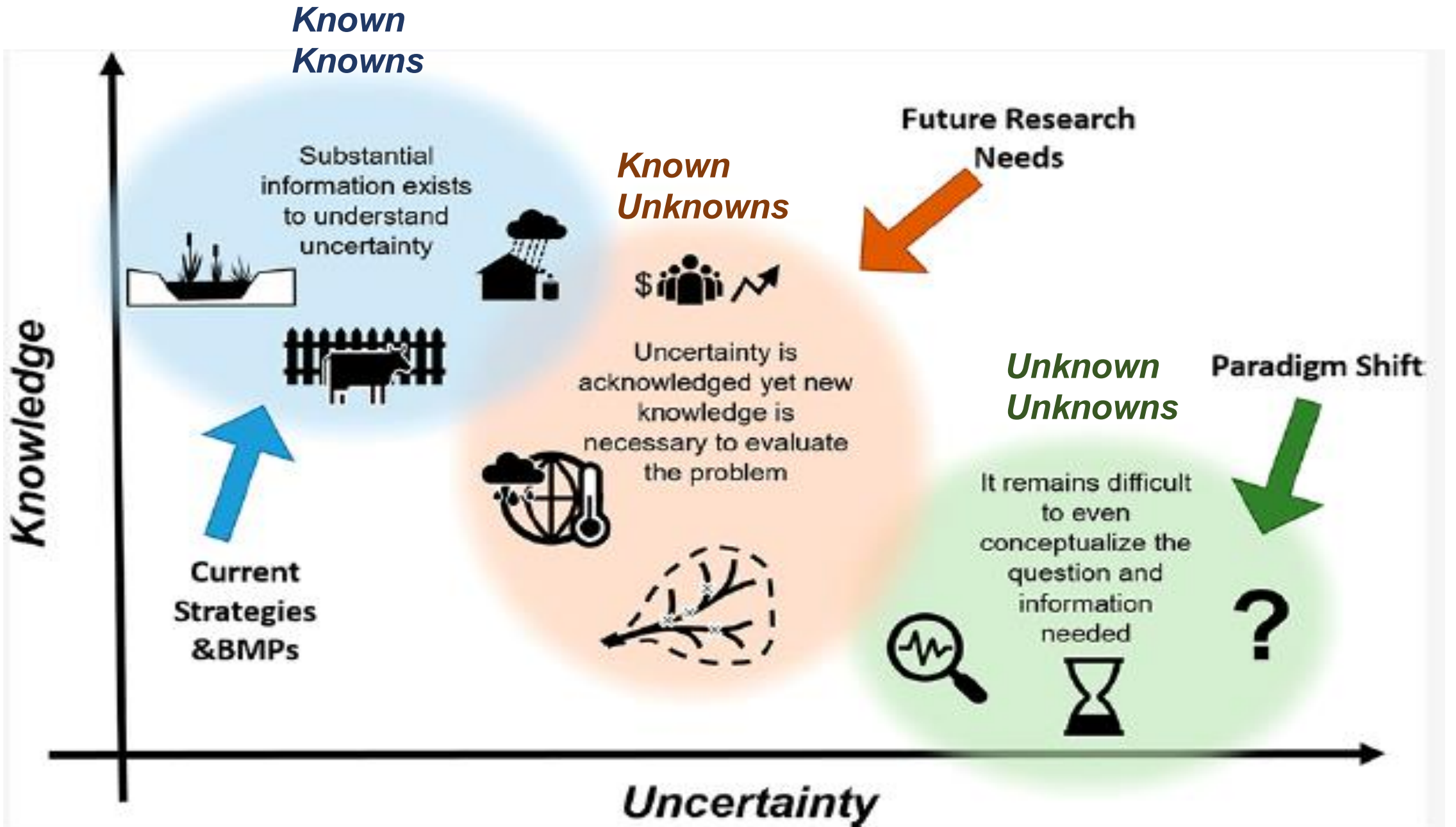
- There may be time horizons appropriate for combining land use change projections into future BMP performance modeling studies

**Closely related infrastructure systems (e.g., storm sewers) not addressed by this review**

- offer opportunities for cross-sector collaboration

**Social science linkages**

- especially with respect to improved implementation, appropriateness of individual/complexes of BMPs





A photograph of a vast cornfield with young green corn plants in the foreground and rows of mature, golden-brown corn in the background. In the distance, there are rolling hills under a blue sky with a single bright lightning bolt striking down. The overall scene is rural and agricultural.

Finalized Report Anticipated: Jan 21, 2022

Thank You

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# Additional Reference Slides

# Review Questions

Using modified systematic literature reviews to inform answers and identify gaps

1. How does climate change affect nutrient/sediment cycling?

17 articles heavily supplemented by rich literature for climate impacts

2. How do climate change and climate variability affect BMP performance?\*

a. By what mechanisms can climate change and climate variability affect BMP nutrient and sediment removal efficiency?

61 that met criteria out of 412 papers identified

b. How does climate change uncertainty affect BMP performance?

14 articles that met criteria out of 172 papers identified

\*Additionally, NOAA funding enabled additional search focused more on BMPs of interest for tidal and habitat purposes; reviewed an additional 33 articles based on search results of 205 papers

3. Which BMPs will likely result in the best water quality outcomes under climate uncertainty?

Will use information from reviews for the other questions

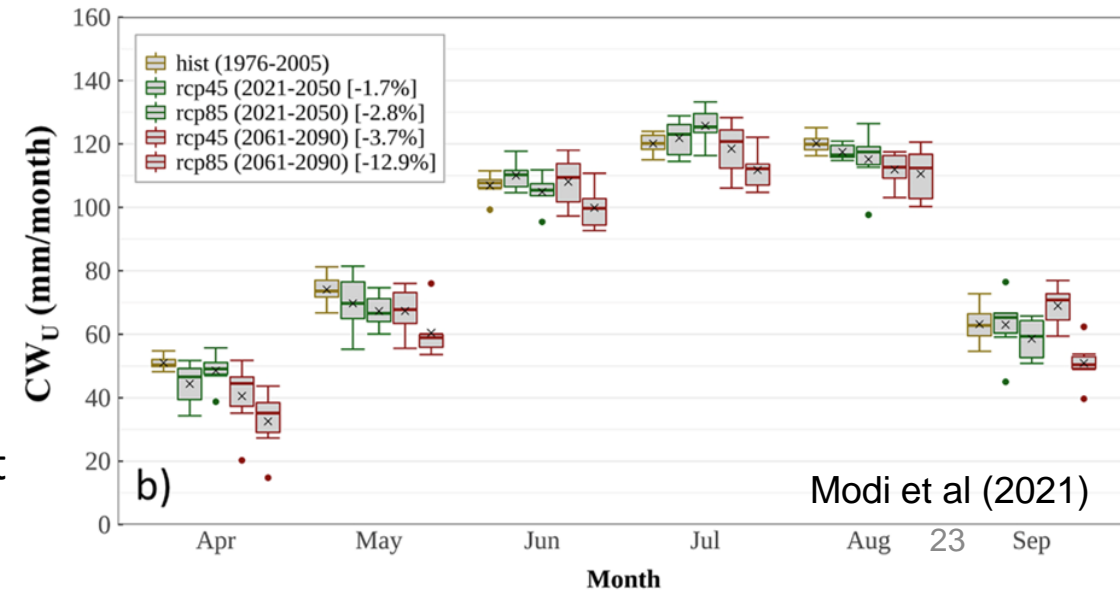
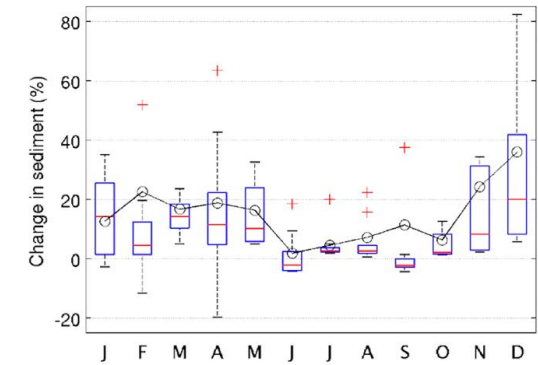
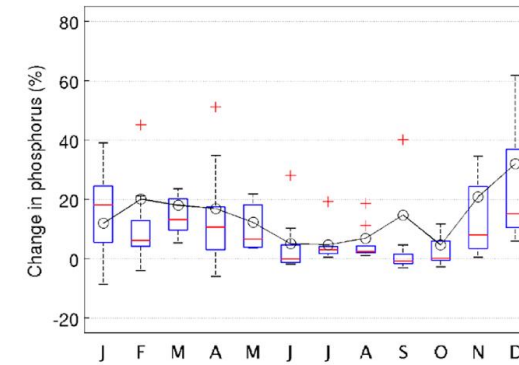
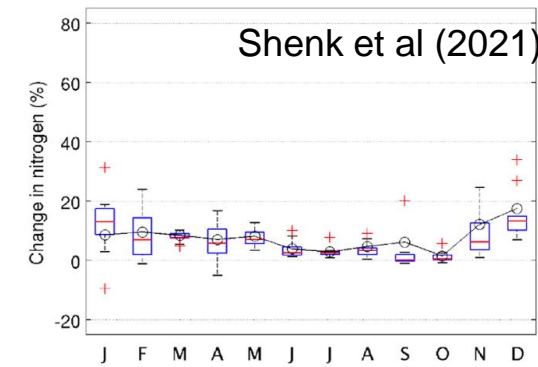
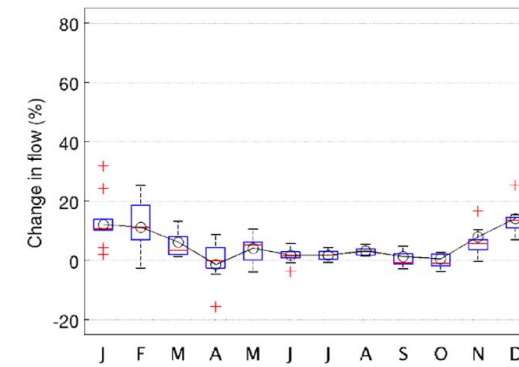
# Expected climate impacts in the Bay and watershed

Changes where we have a relatively strong understanding of likely futures...

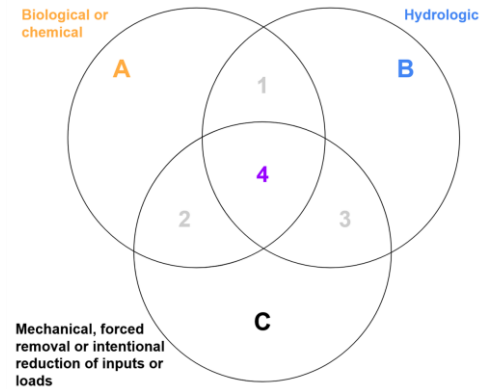
- Precipitation (increase but variable)
- Temp (increase)
- SLR (increase)

Changes where we still have more conflicting possibilities...

- ET (depends on  $\text{CO}_2$ )
- Streamflow (increase but variable)
- Soil moisture (variable)
- Nutrient/sediment cycling and export (increase but variable)



Modi et al (2021)



BMP or BMP group	Assignment
Ag Nutrient Management	4 or C (rate/core only)
Tillage Management	B
Cover Crops	1 or A
Urban Nutrient Management	4
Pasture Management	1
Forest Harvesting	B
Manure Incorporation	1 or B
Land Retirement	1 or 4
Wetland Rehabilitation	A or B
Tree Planting	A
Grass Buffers	1
Forest Buffers	1
Animal Waste Management Systems (AWMS)	C
Stream restoration	1
Wet ponds and wetlands	1
Tidal wetland restoration	1
Nontidal wetland restoration	1
Living shoreline	1
Oyster restoration or aquaculture	2

## Where priority BMPs fit

### Pros

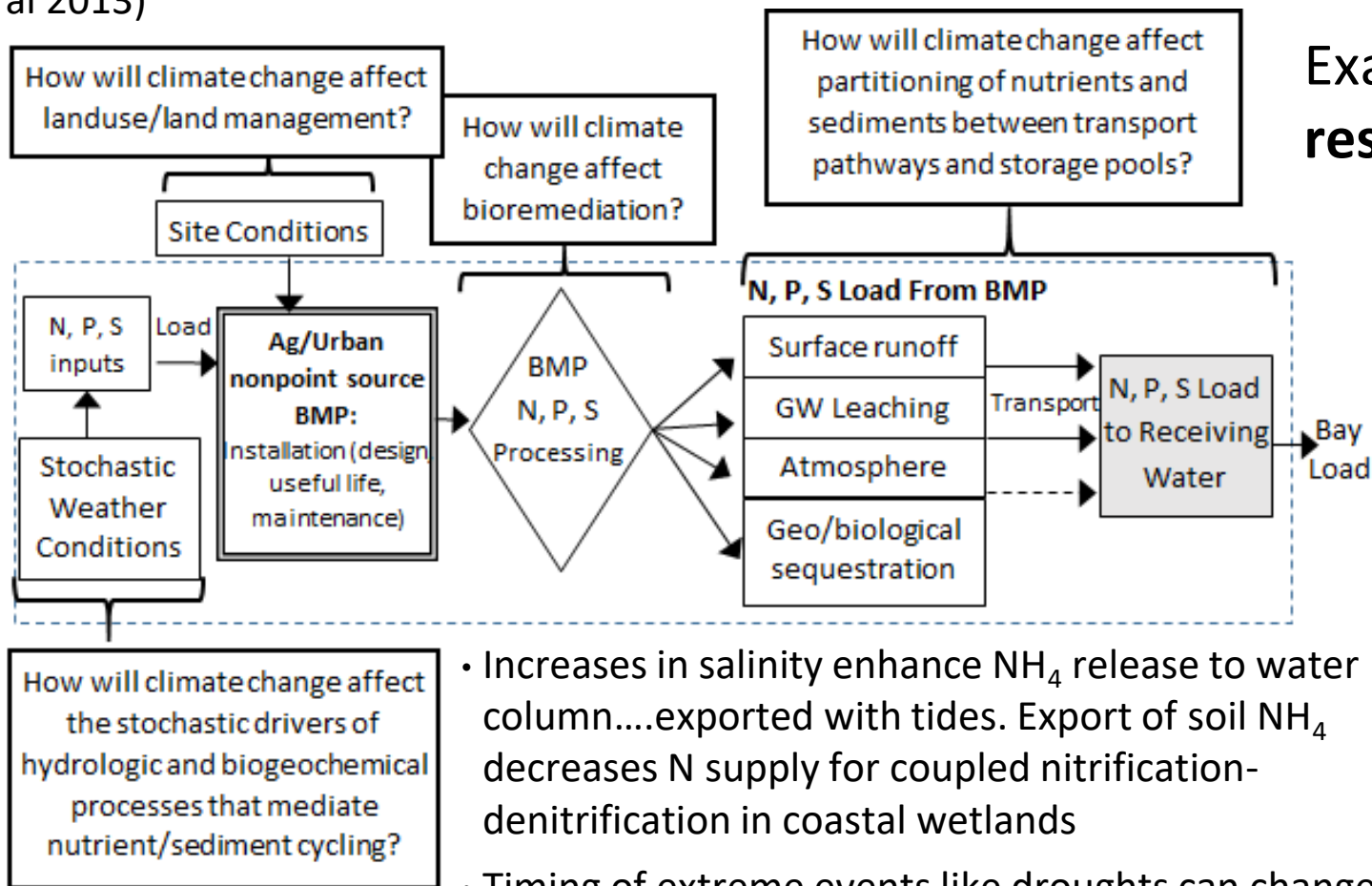
- Enables us to think through some of the relative uncertainties and complexities between different practices, or within the same practice, more easily
- Helps to separate out some practices and identify vulnerabilities more easily

### Cons and caveats

- This lumps a lot of unique processes together. Same goes for complexity of the BMPs
- This is illustrative. It is neither comprehensive nor definitive
- A lot of BMPs fall in zone 1
- Subjective

- Upland management impacts sediment quality/availability— how does climate impact these processes?
- Restoring tidal hydrology may enable salinity to travel farther inland.... Ag land use exposed to low levels of salinity can release  $\text{NH}_4$  (Ardon et al 2013)

- Increased temps and  $\text{CO}_2$  affect growth of vegetation (greater N uptake and temporary storage)
- What role does evolving balance of freshwater inputs play? (increased precip... increased streamflow) - inconclusive
- What does the literature say about changes to soil chemistry and biogeochemical functions? Short answer: it's complicated and varies by wetland type, site factors

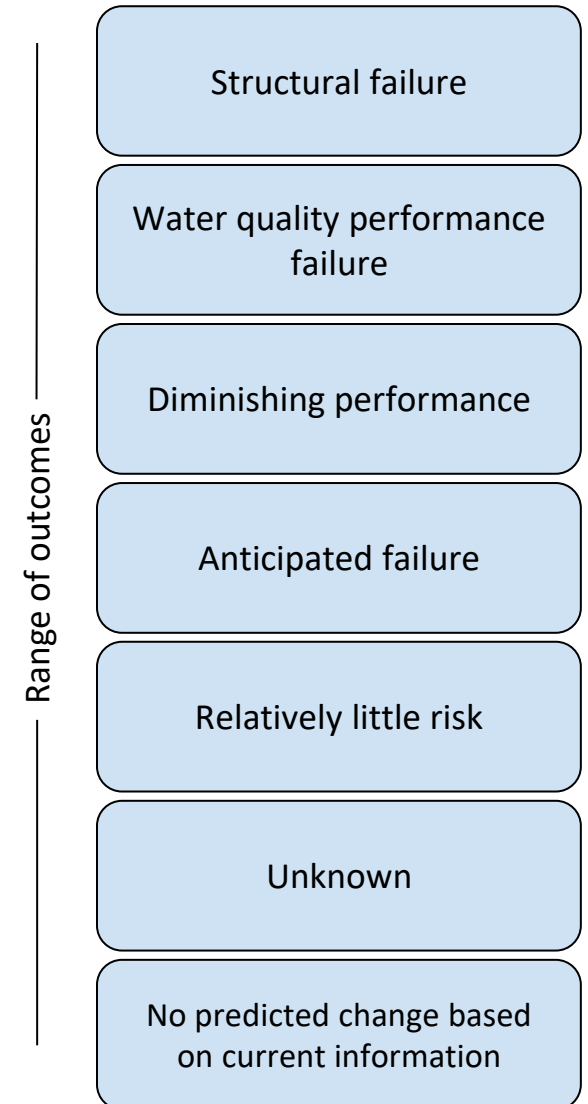


## Example BMP: Tidal wetland restoration

- Saltwater incursion into historically freshwater wetland systems impact microbial communities; restoring freshwater may not fully restore microbial function but can improve sensitives (Huang et al 2021)
- Rising sea levels and increased storm surge threaten coastal wetland systems
- Sediment accretion influenced by many factors
  - Liu et al (2021) suggests sediment availability is driver for success of coastal wetland restoration
- Interaction with nature-based BMPs (living shorelines) or natural barriers (oyster reefs) can slow marsh retreat (Ridge et al 2017)

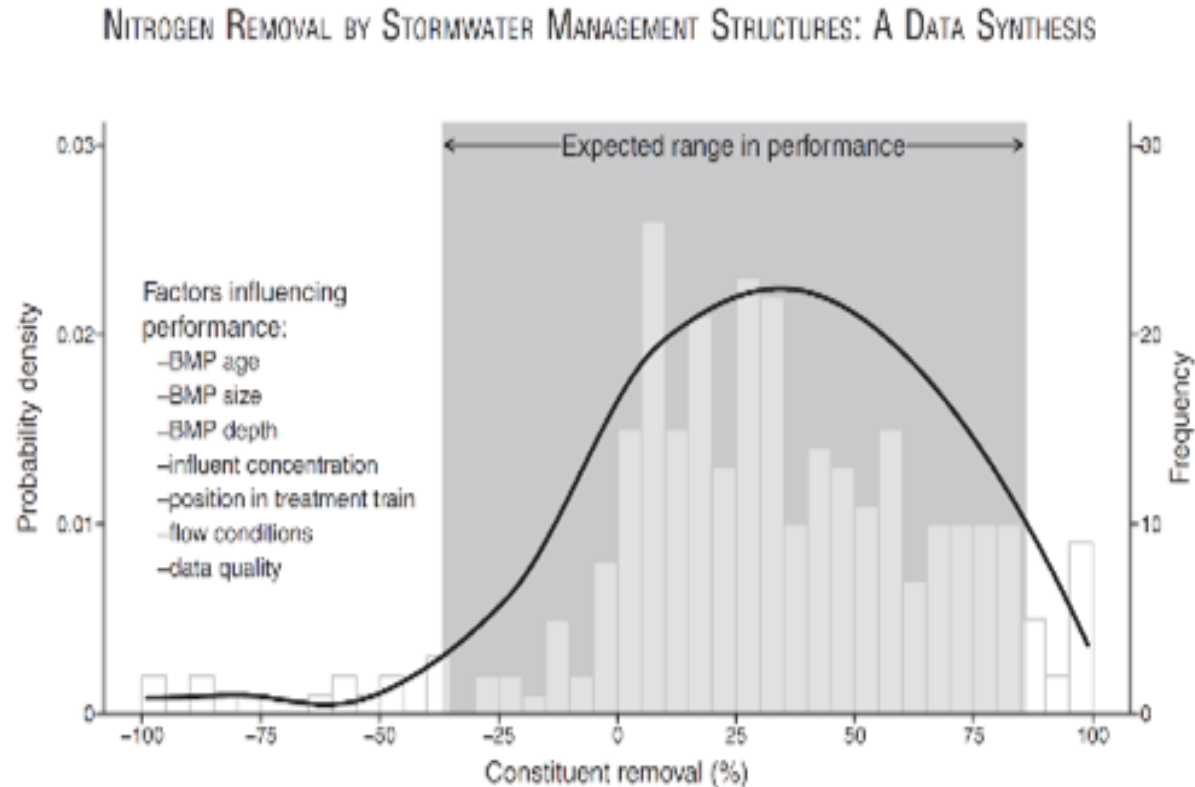
# Leveraging other conceptual frameworks

- We can apply our framework alongside other conceptual models to characterize risks and uncertainty, and to better understand our knowledge gaps and needs.
  - For example, CSN's risk spectrum (Wood 2021) for stormwater BMPs can be useful for other sectors' BMPs, with modifications  
Given level of available info: we combine expected future climate factors (CO<sub>2</sub>, temp, precip) with generalized conceptual model of BMP primary mechanisms
  - To identify mechanisms and BMPs most at-risk, compared with snapshot of most-implemented BMPs or BMPs with greatest overall reductions, this can help illuminate the overall question of how climate change impacts efforts to restore and protect the Chesapeake Bay.





# Knowledge gaps (abridged - part 1)



Koch et al (2014)

- More long term studies of BMPs are needed (always), but especially for BMPs that are particularly complex or are vulnerable to climate change
- Literature rarely describes maintenance or upkeep of longer term practices; almost never considers BMP failure
- Studies on the non-linear responses of the system to climate variability/change, and their interaction with other anthropogenic stressors