Chesapeake Bay BMP Climate Synthesis Report

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

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Water Quality Goal Implementation Team
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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

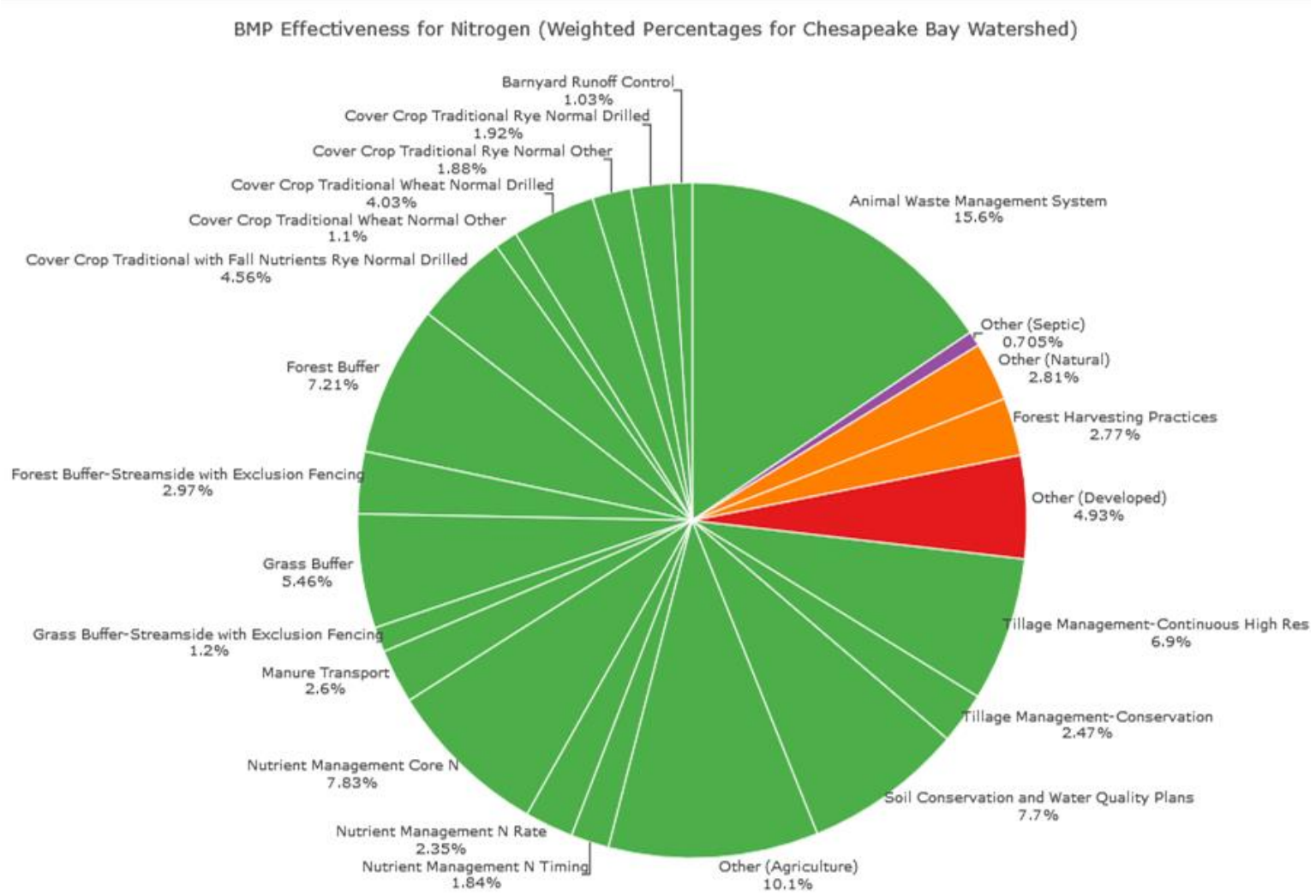
- Warmer, Wetter Winters & Springs

- Nitrogen Cycle Changes
  - Increased temp → increases in mineralization and nitrification, generally results in greater N yields
  - Increases in 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?

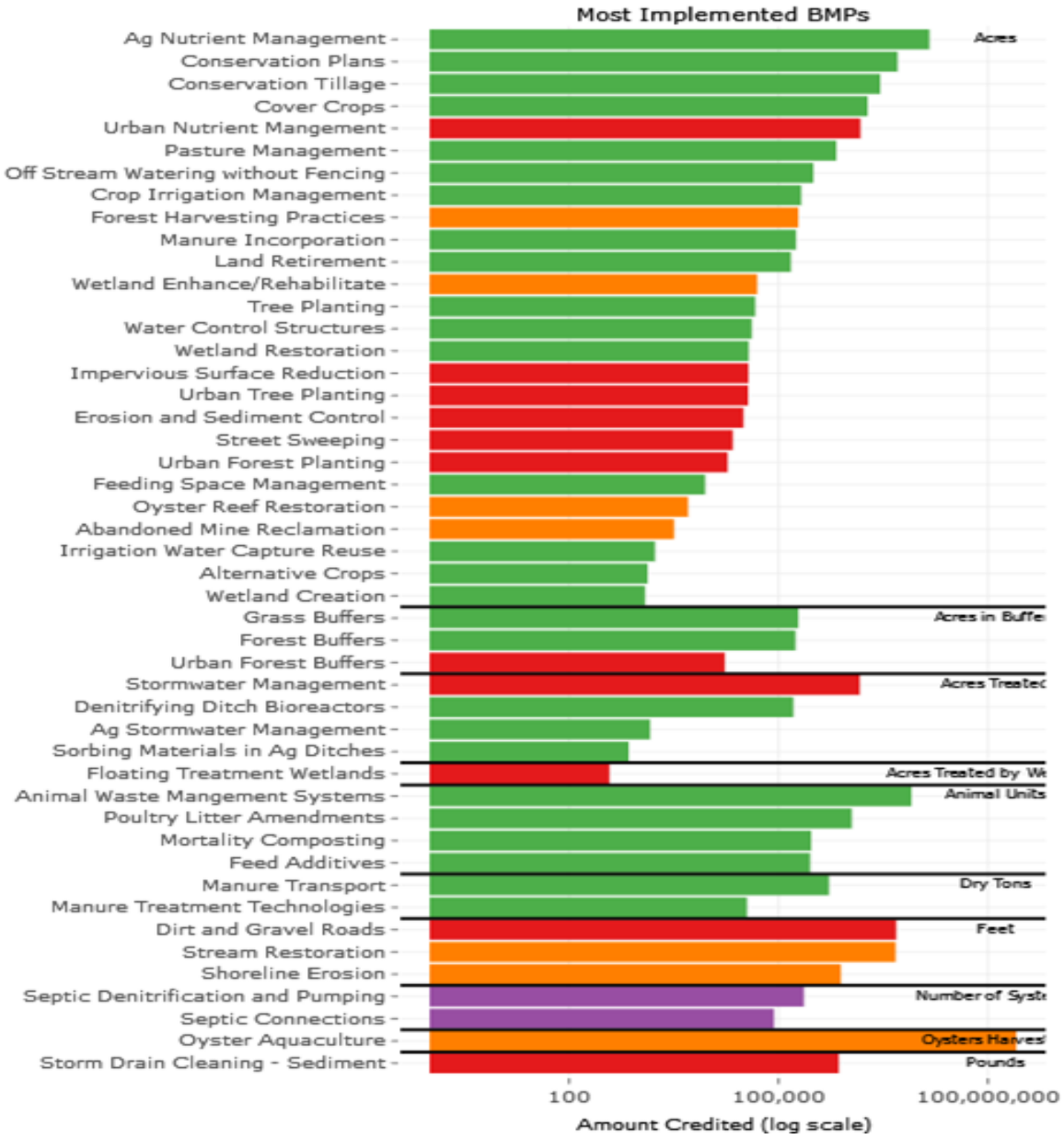
Effectiveness of BMPs



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?

Implementation of BMPs



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2. How does climate change affect BMP performance?

Most implemented	NOAA
By units planned implementation/treatment	
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?

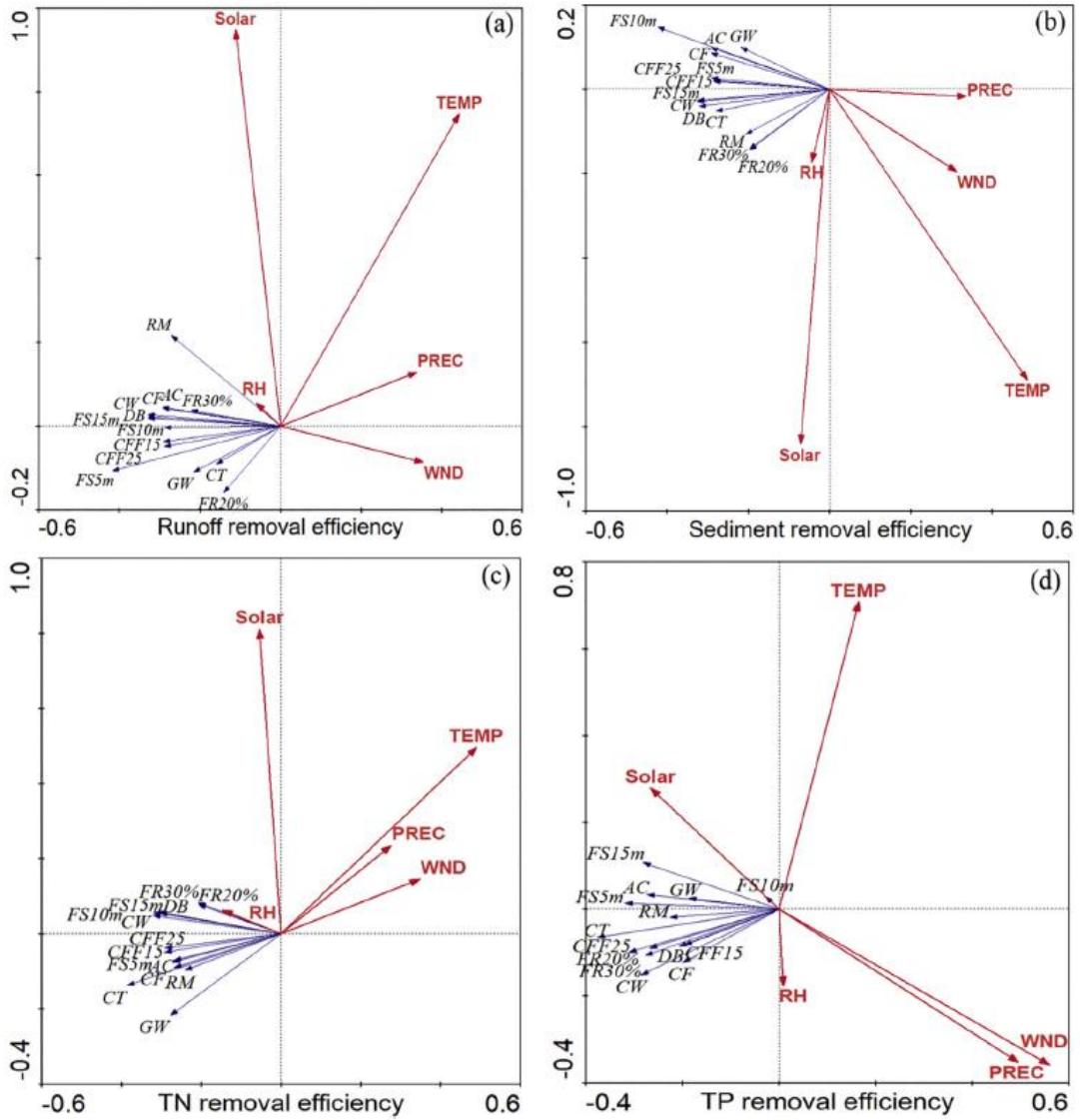


Fig. 5. Relationships between annual runoff (a), sediment (b), TN (c), and TP (d) removal efficiencies of 14 BMPs with climate factors, including precipitation (PREC), temperature (TEMP), solar radiation (Solar), relative humidity (RH), and wind speed (WND), during 2020–2099. Abbreviations of BMPs are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

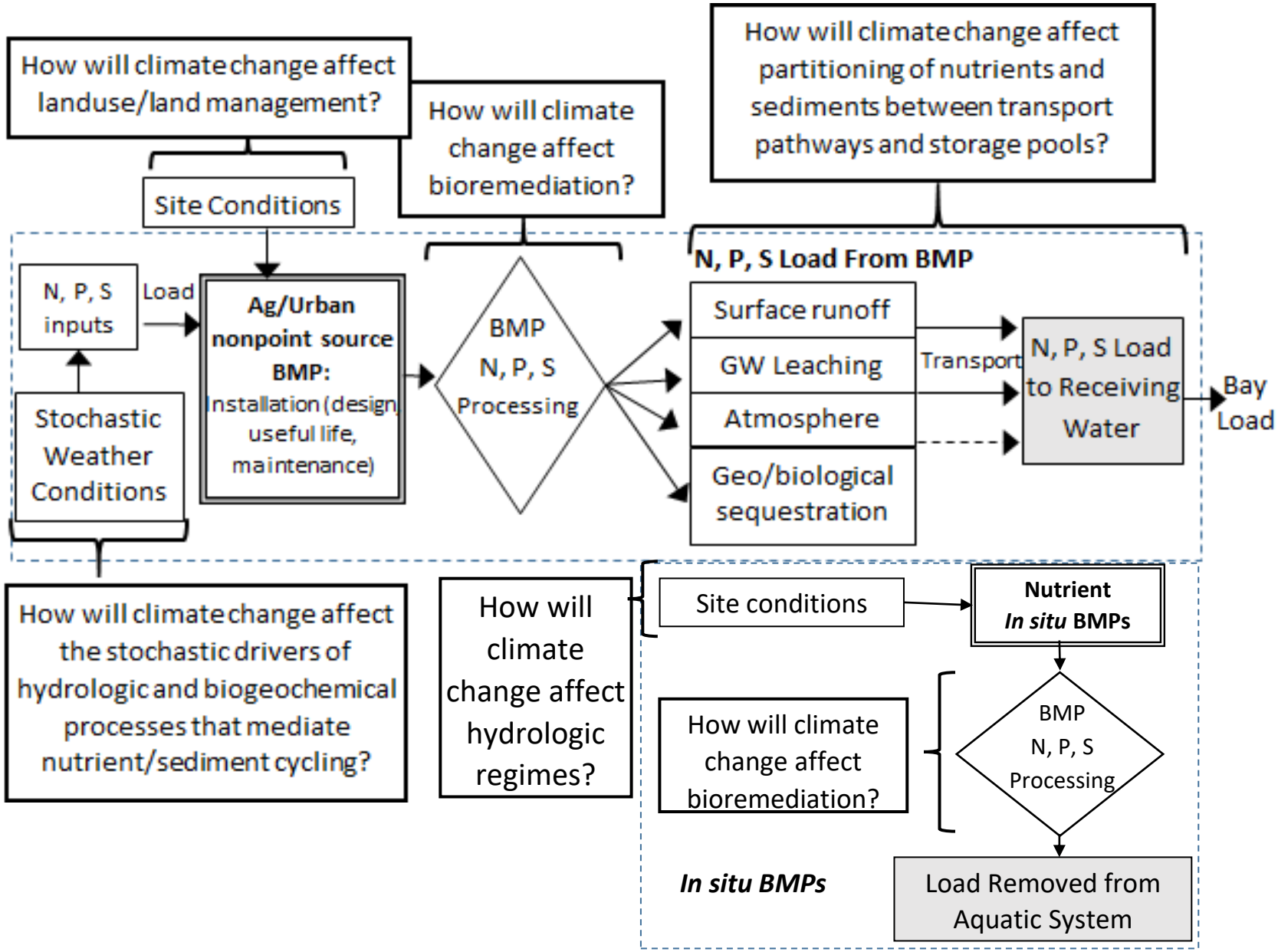
Future Climate Factors & (modeled) BMP Performance

Emerging area of research…

Need strengthened understanding of causal impacts of climate

Qiu et al (2020)

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

2. How does climate change affect BMP performance?

BMPs Will Have to Deal with Greater Fluxes & More Variability

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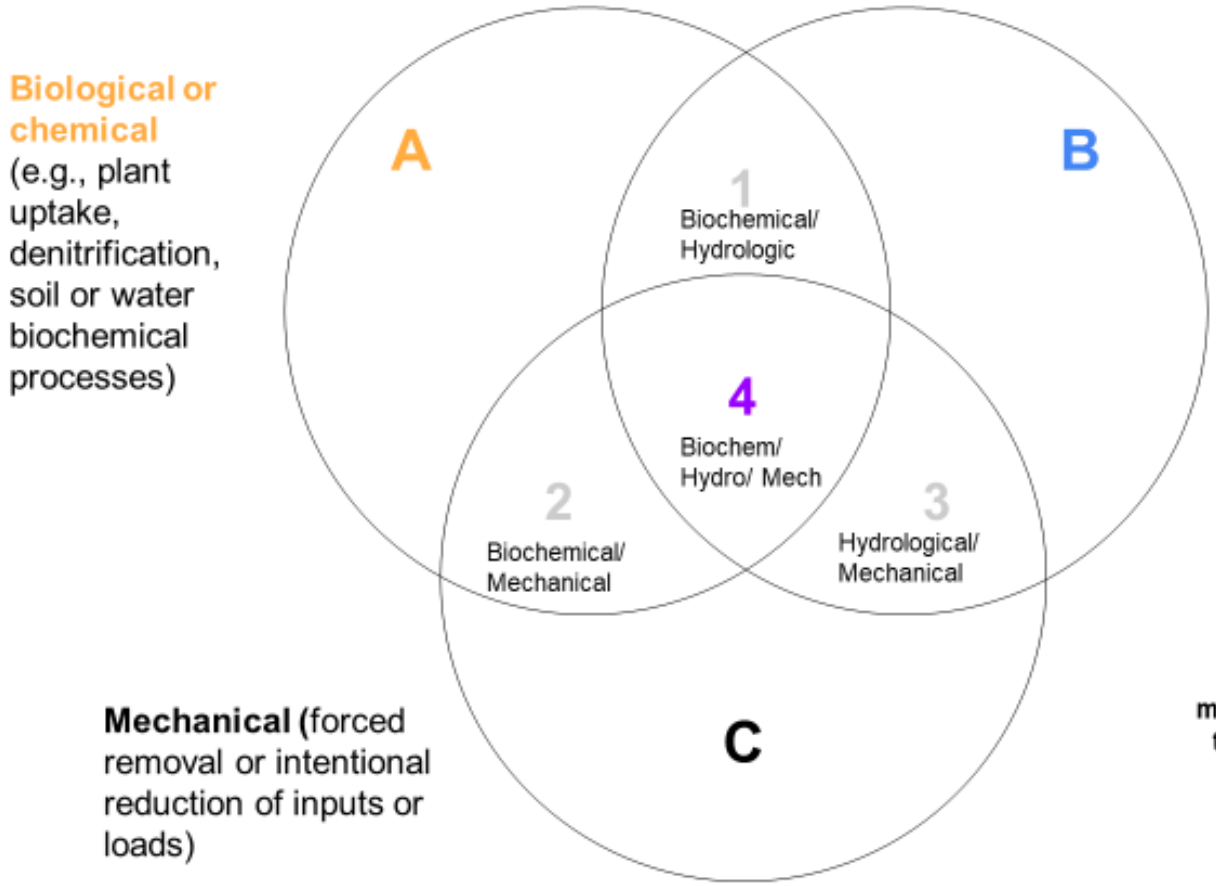
3. Which BMPs will likely result in the best water quality outcomes under climate uncertainty?

BMP Classification Scheme



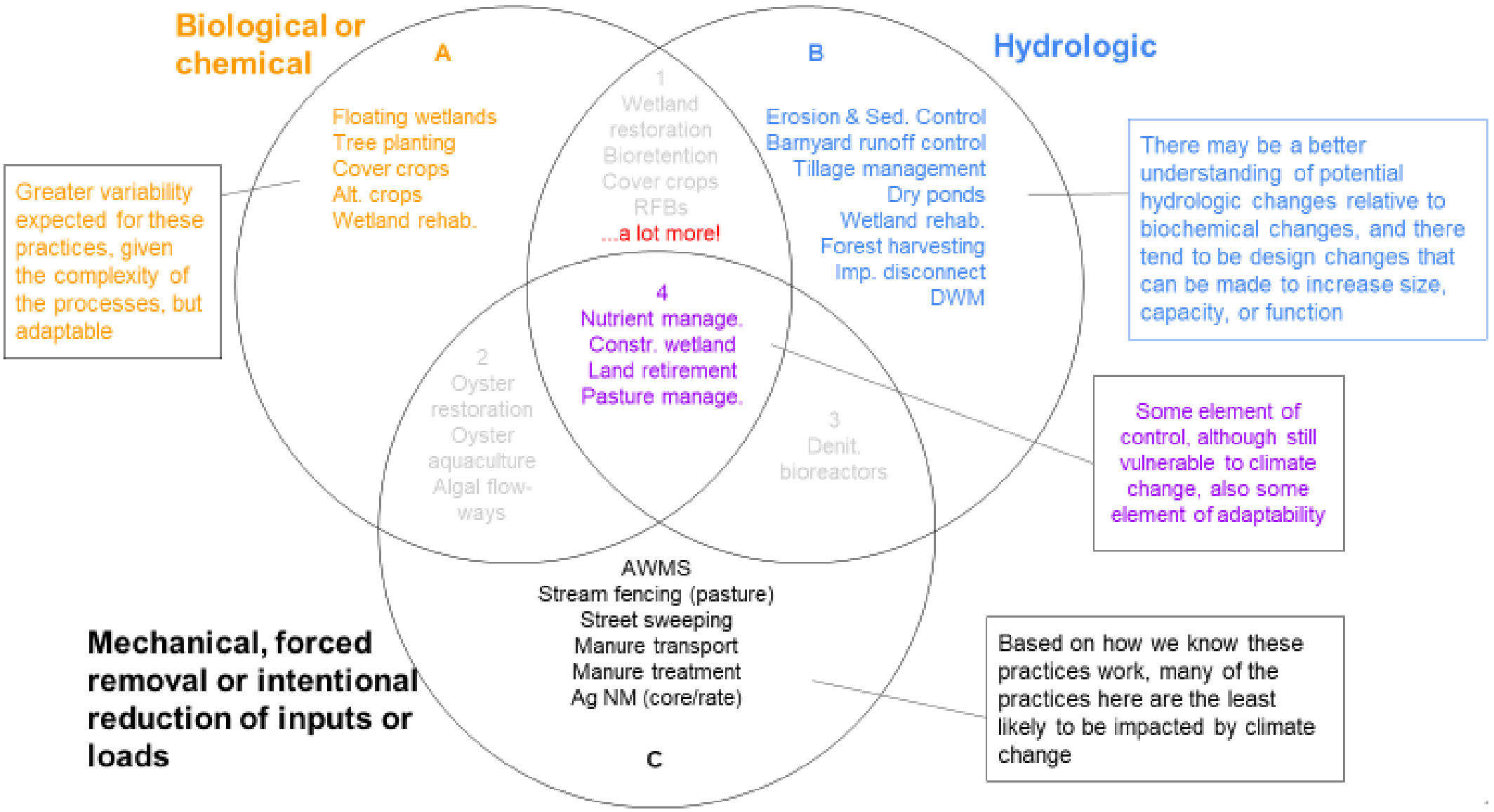
Biological or chemical (e.g., plant uptake, denitrification, soil or water biochemical processes)

Hydrologic (e.g., water capture, retention, infiltration)

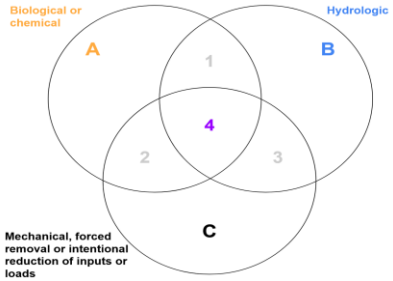
Mechanical (forced removal or intentional reduction of inputs or loads)

Conceptual model of BMP categorization based on mechanisms and processes used to reduce, remove or transform nutrients or sediment

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_2	Diminishing performance from increased variability, but countered by increased plant biomass from CO_2 effect[1]	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_2	Diminishing performance from increased water balance but countered by increased plant biomass from CO_2 effect[1]	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_2	Diminishing performance from increased variability but countered by increased plant biomass from CO_2 effect[1]	Monitoring; develop more adapted rapidly maturing species

[1] Although evidence exists that many of these natural type BMPs may function better under higher temperatures and CO_2 concentrations as long as moisture and nutrients are not limiting (this also depends on plant type, C3 or C4 species).

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)

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)

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)**

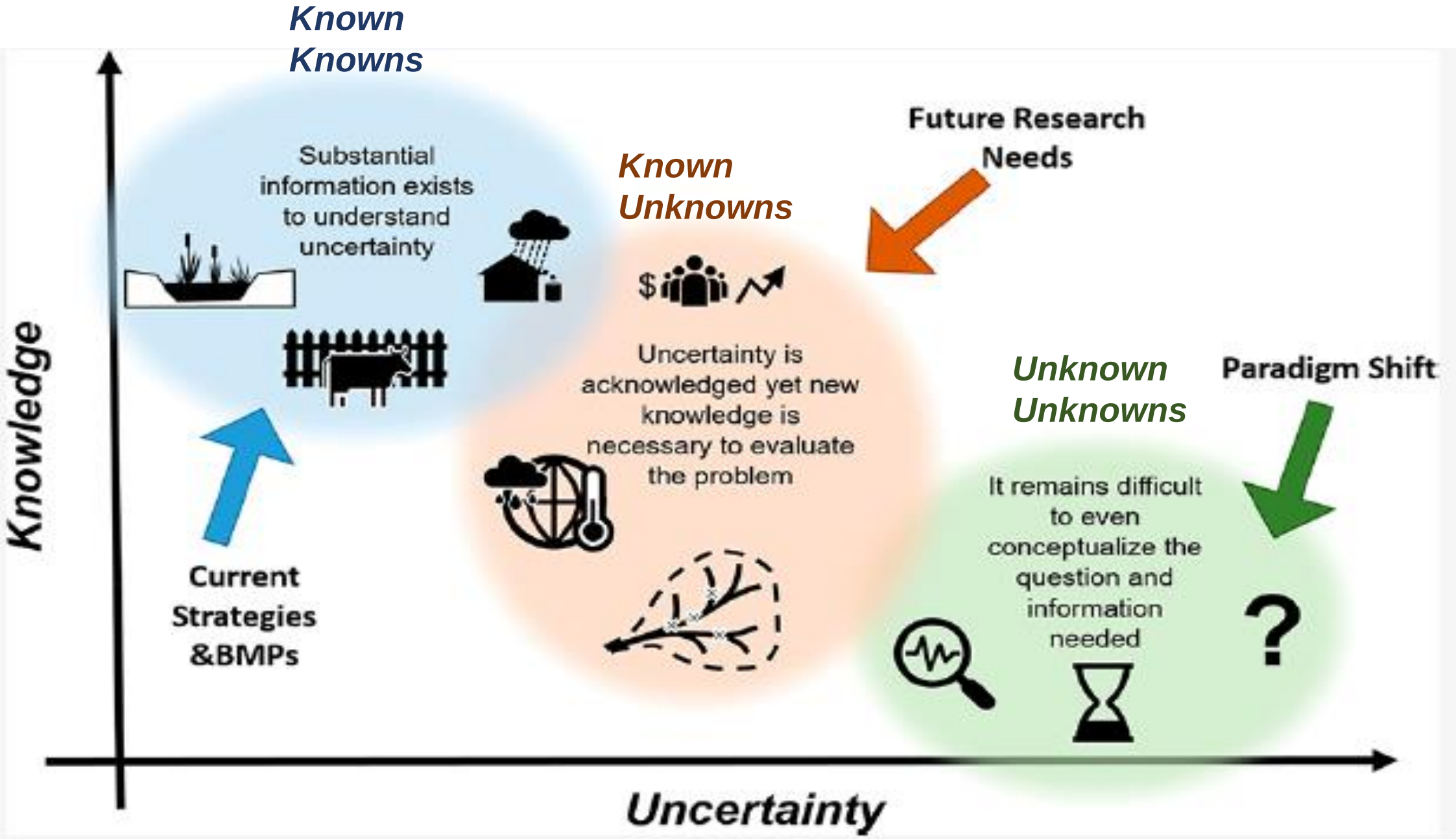
- There may be time horizons appropriate for combining land use change projections into future BMP performance modeling studies

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



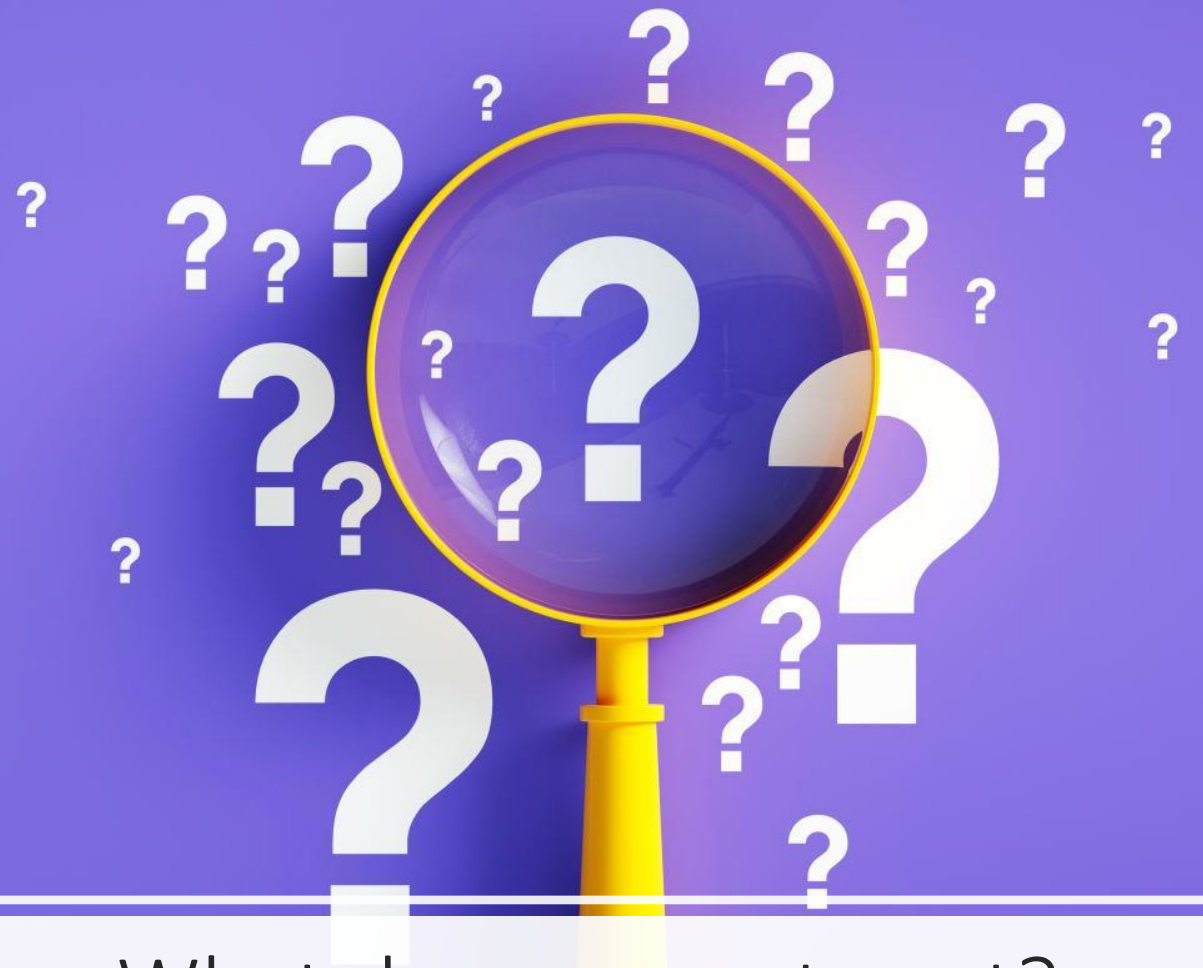
Lintern et al (2020)

Recommendations

- Develop mechanisms for publication of aggregated BMP inspection failure data
- Encourage and incentivize partnerships between researchers and jurisdictions' BMP verification programs to collect and publish more long-term BMP performance data
- More mechanistic BMP modeling studies

Recommendations

- Leverage existing adaptive management efforts to establish a CBP agenda for research and science needs related to BMPs and climate change, with priority on communication of “no-lose” directions.
- Develop mechanisms of quantifying BMP efficiency uncertainty under climate change.
- Expert elicitation to determine alterations to BMP Efficiencies. (GIT-funding?)



What do you want next?

Report released: Jan 21, 2022

https://bit.ly/BMP-CC-synth

Thank You

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Photo: Chesapeake Bay Program

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

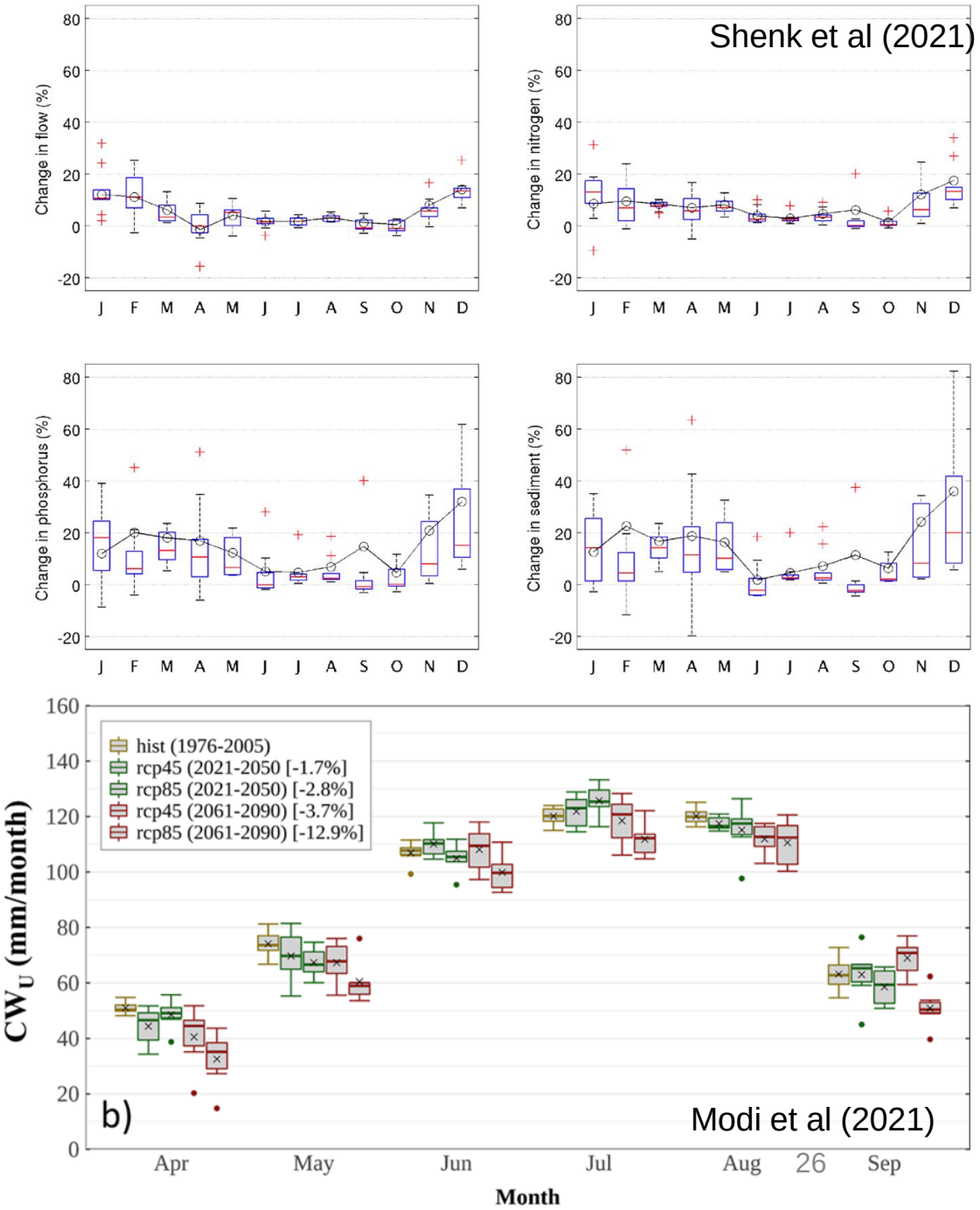
Expected climate impacts in the Bay and watershed

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

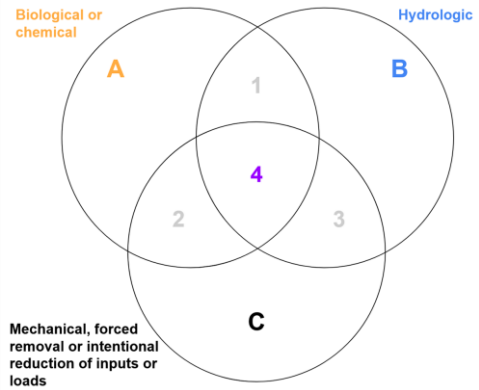
- Precipitation (increase but variable)
- Temp (increase)
- SLR (increase)

Changes where we still have more conflicting possibilities...

- ET (depends on CO_2)
- Streamflow (increase but variable)
- Soil moisture (variable)
- Nutrient/sediment cycling and export (increase but variable)



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

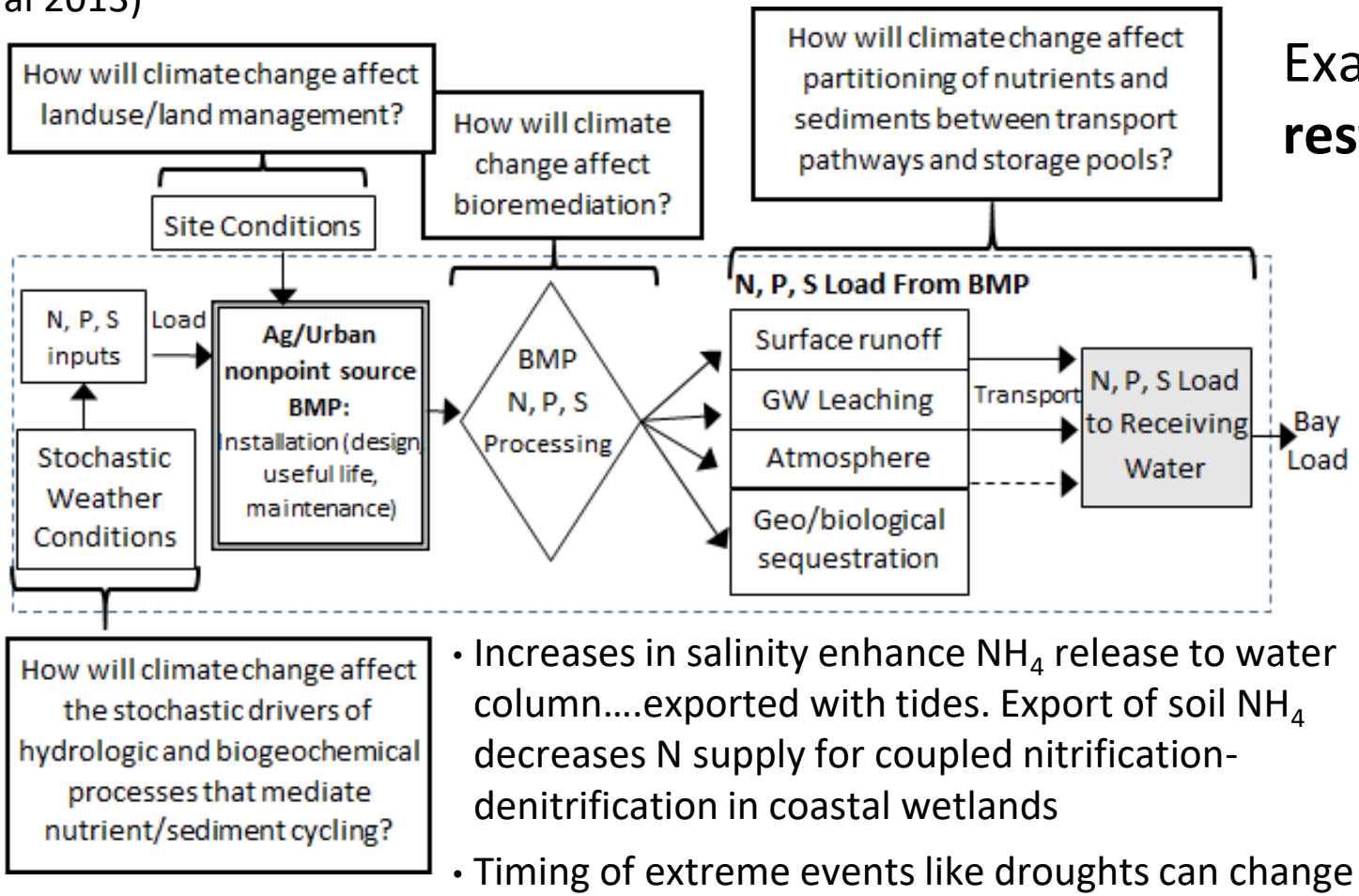
- Enables us to think through some of the relative uncertainties and complexities between different practices, or within the same practice, more easily
- Helps to separate out some practices and identify vulnerabilities more easily

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 NH_4 (Ardon et al 2013)

- Increased temps and 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



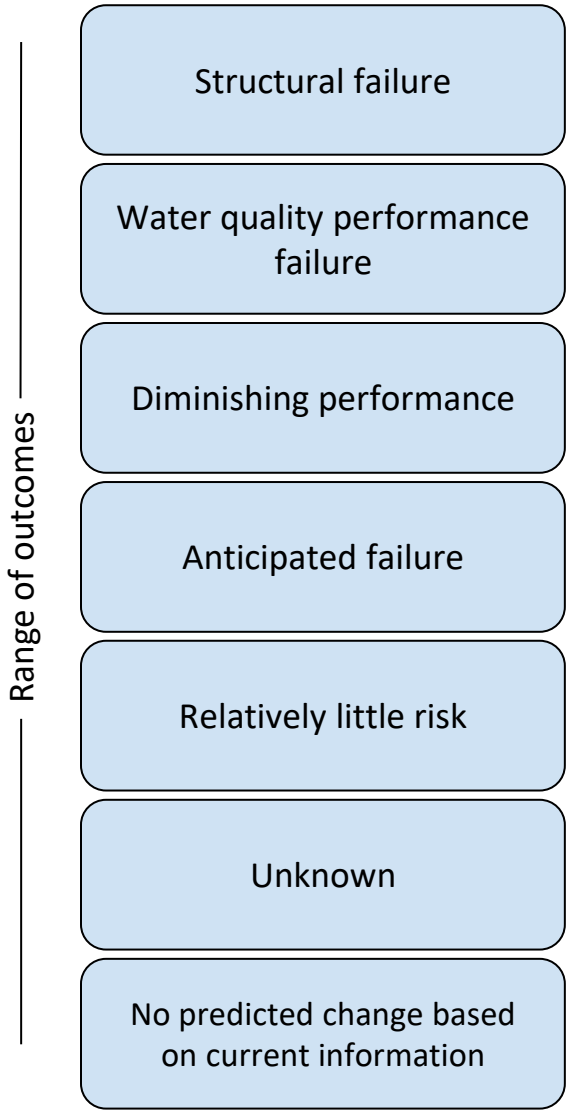
- Increases in salinity enhance NH_4 release to water column….exported with tides. Export of soil NH_4 decreases N supply for coupled nitrification-denitrification in coastal wetlands
- Timing of extreme events like droughts can change form of exported N

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)

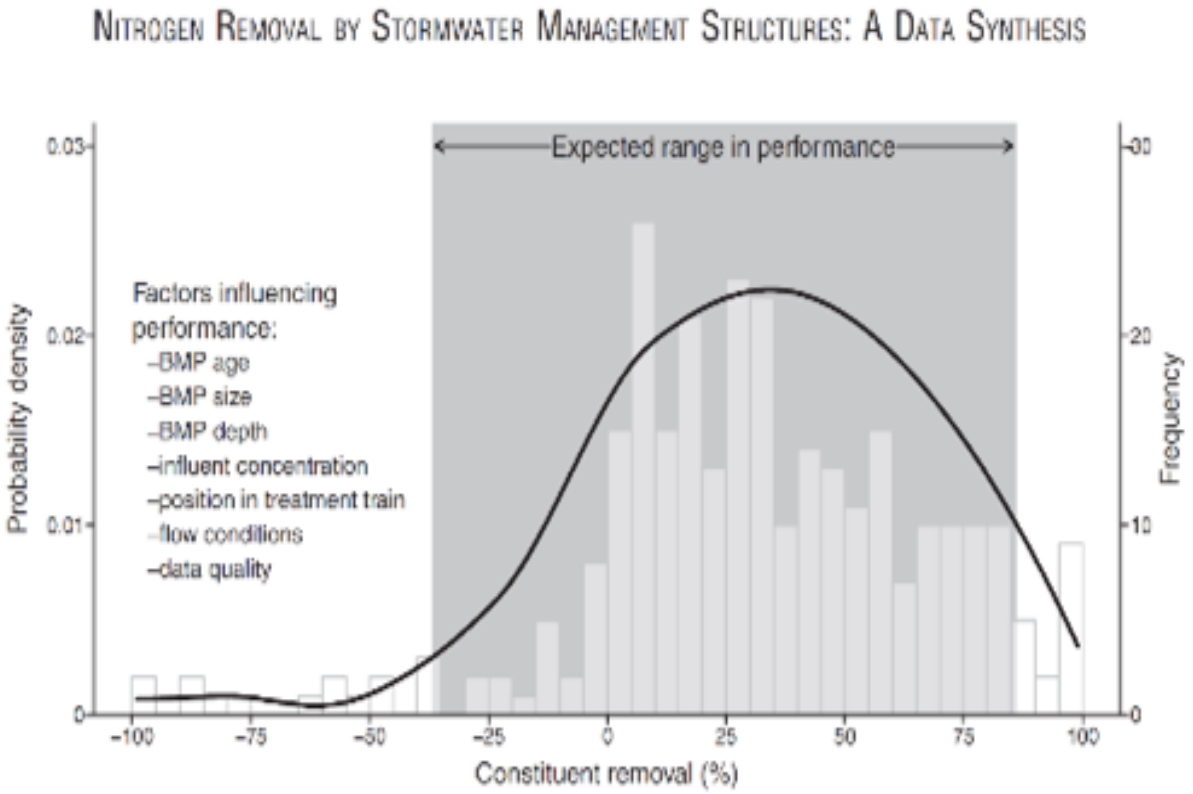
Leveraging other conceptual frameworks

- 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_2, 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.



Wood, (2021) https://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2021/03/Memo-4_BMP-Vulnerability-Analysis_Final.pdf

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