




# A SWAT-Based Framework for Understanding Sediment and Nutrient Dynamics Under Best Management Practices in the NYC Watershed

AgMIP

NASA

COLUMBIA CLIMATE SCHOOL
CENTER FOR CLIMATE SYSTEMS RESEARCH

CORNELL UNIVERSITY

TEXAS A&M AGRILIFE RESEARCH

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NYC Environmental Protection

Watershed Agricultural Council


# Intro to AgMIP

A global network of 1200+ agriculture, climate, and food researchers

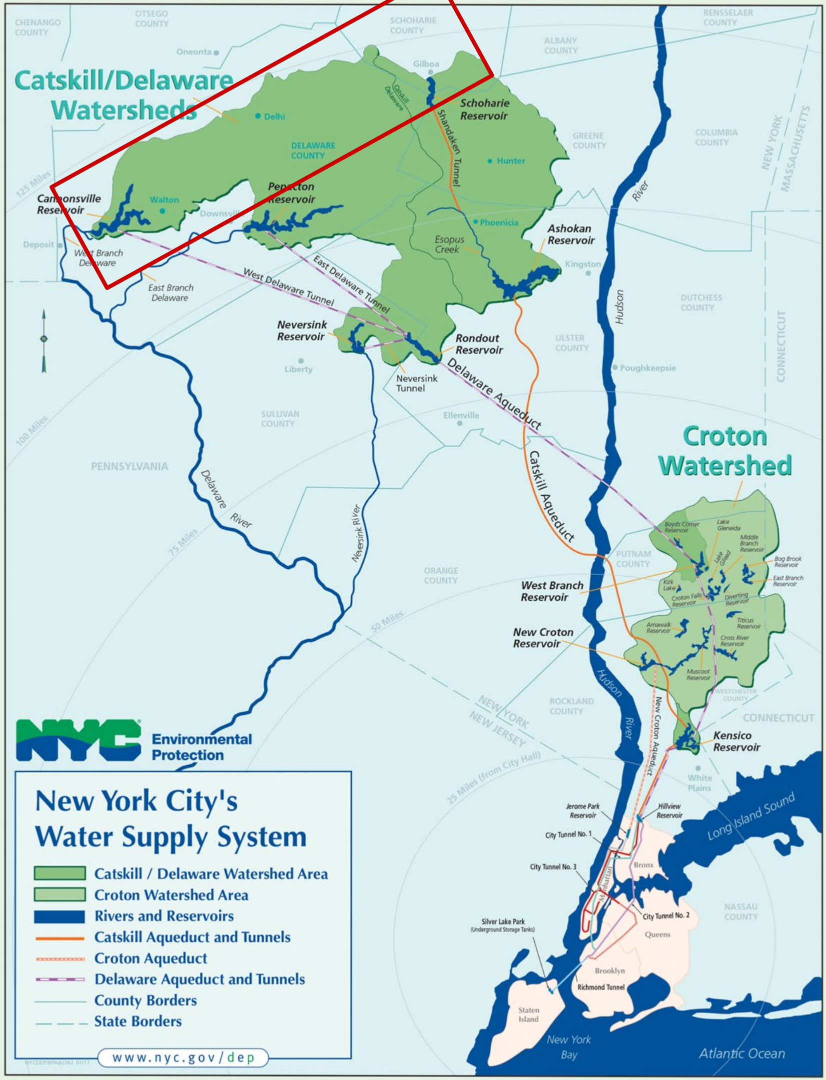
Convenes scientists and stakeholders to conduct multi-model assessments

Projects biophysical and economic impacts of practices, technologies, and incentives for current and future climate conditions

Outcome: Provide science-based agricultural decision-making models and assessments of climate change to achieve local-to-global food security and sustainability

# NYC's Water Supply System

- Transports surface water up to 125 miles from NYC
- 19 reservoirs
- Supplies drinking water to ~8.5 million people
- 90% of the supply delivered without filtration
  - The "Champagne" of drinking water!
- Project focus is on the Cannonsville Reservoir area (shown in red)
- Most agriculture in the watershed occurs within the study area



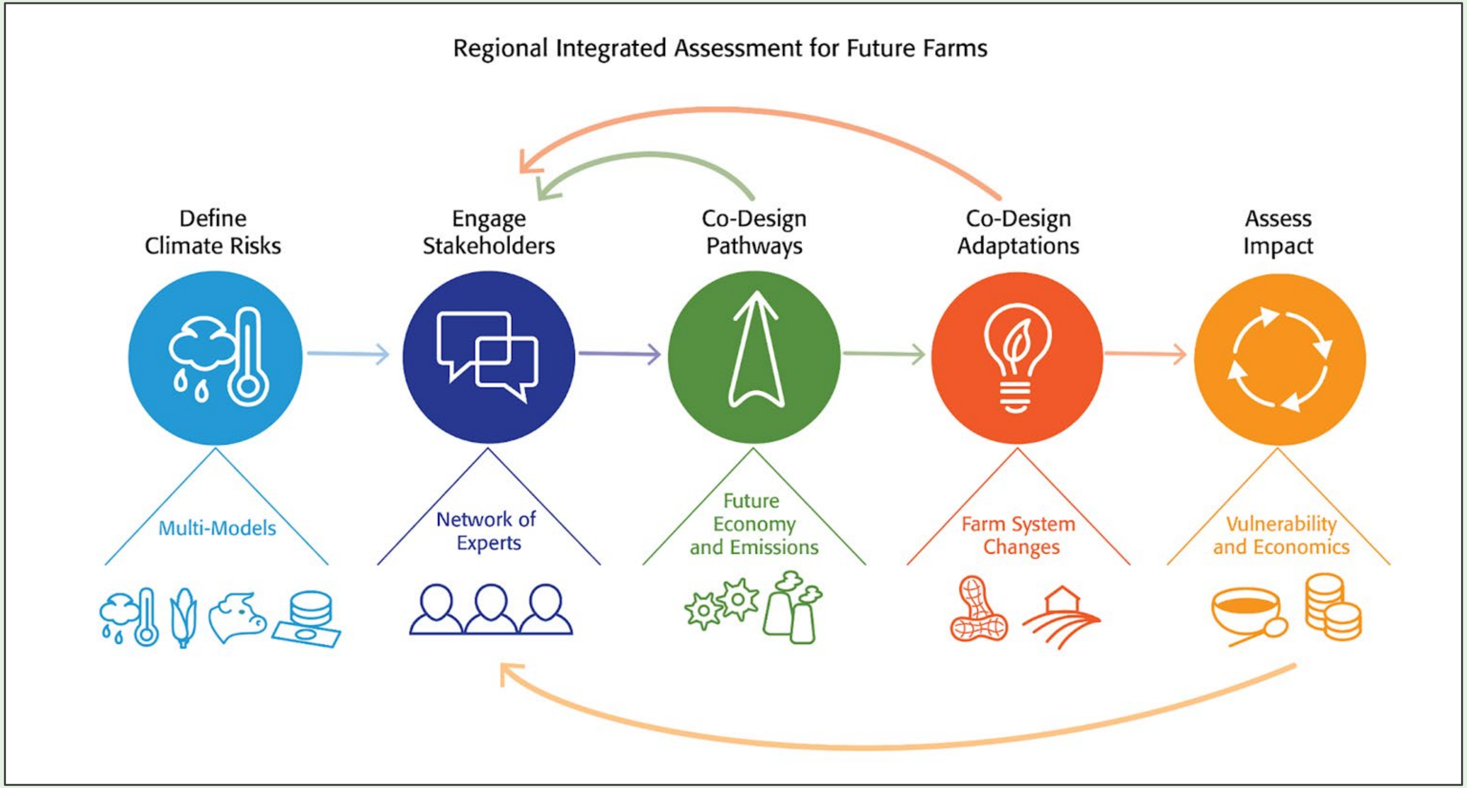
# Core Project Research Questions

How will current agricultural BMPs function under projected climate change?
How can BMPs be improved so that they continue to protect water quality under climate change?

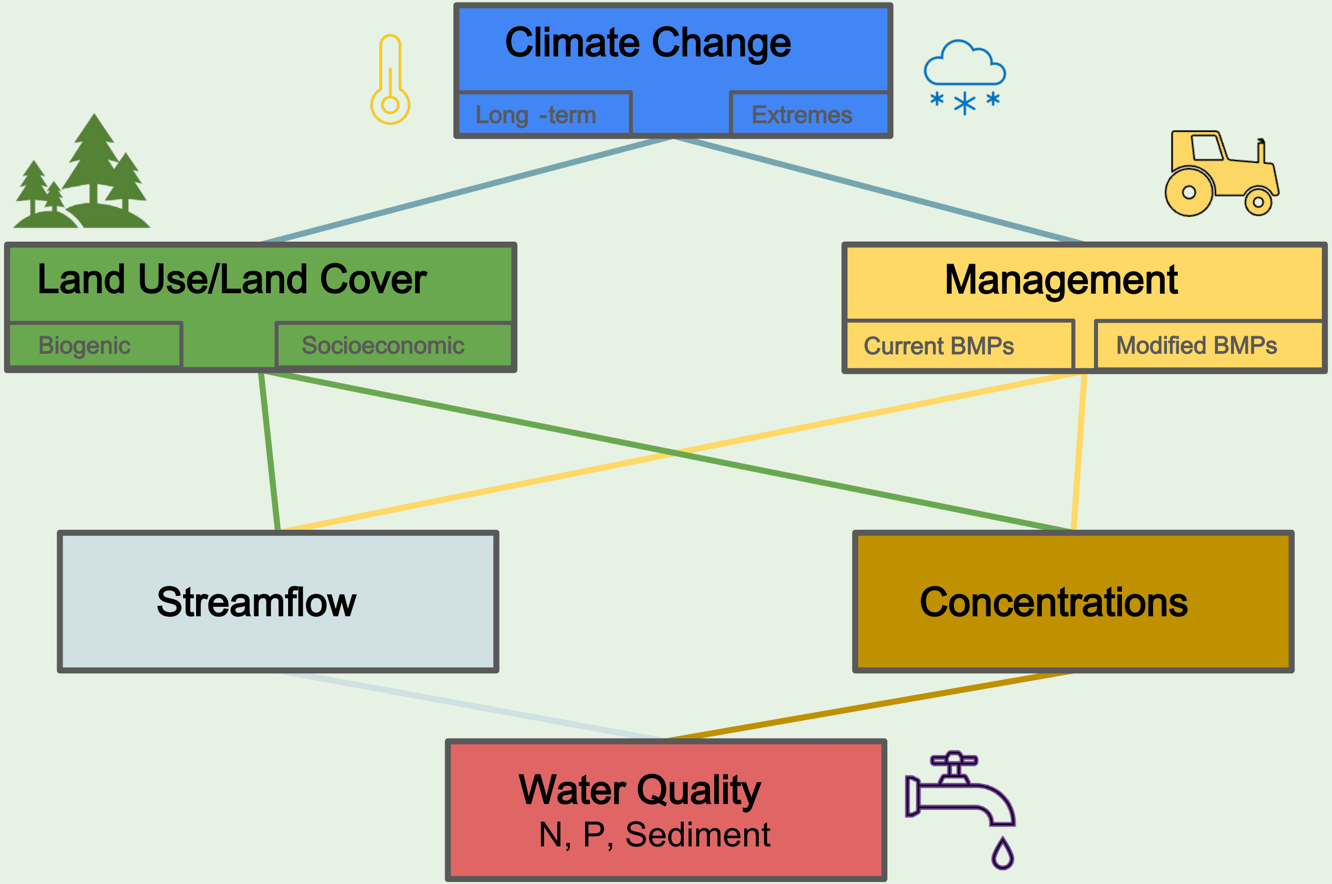
How will crops, livestock, and ecosystems respond to climate change?
How will altered ecosystems impact water quality under climate change?

What broader socioeconomic trends need to be accounted for in the region?
How do shifts in production systems impact BMP implementation under climate change?

# AgMIP's Stakeholder-Driven Research Protocols



# Simplified Theory of System Change



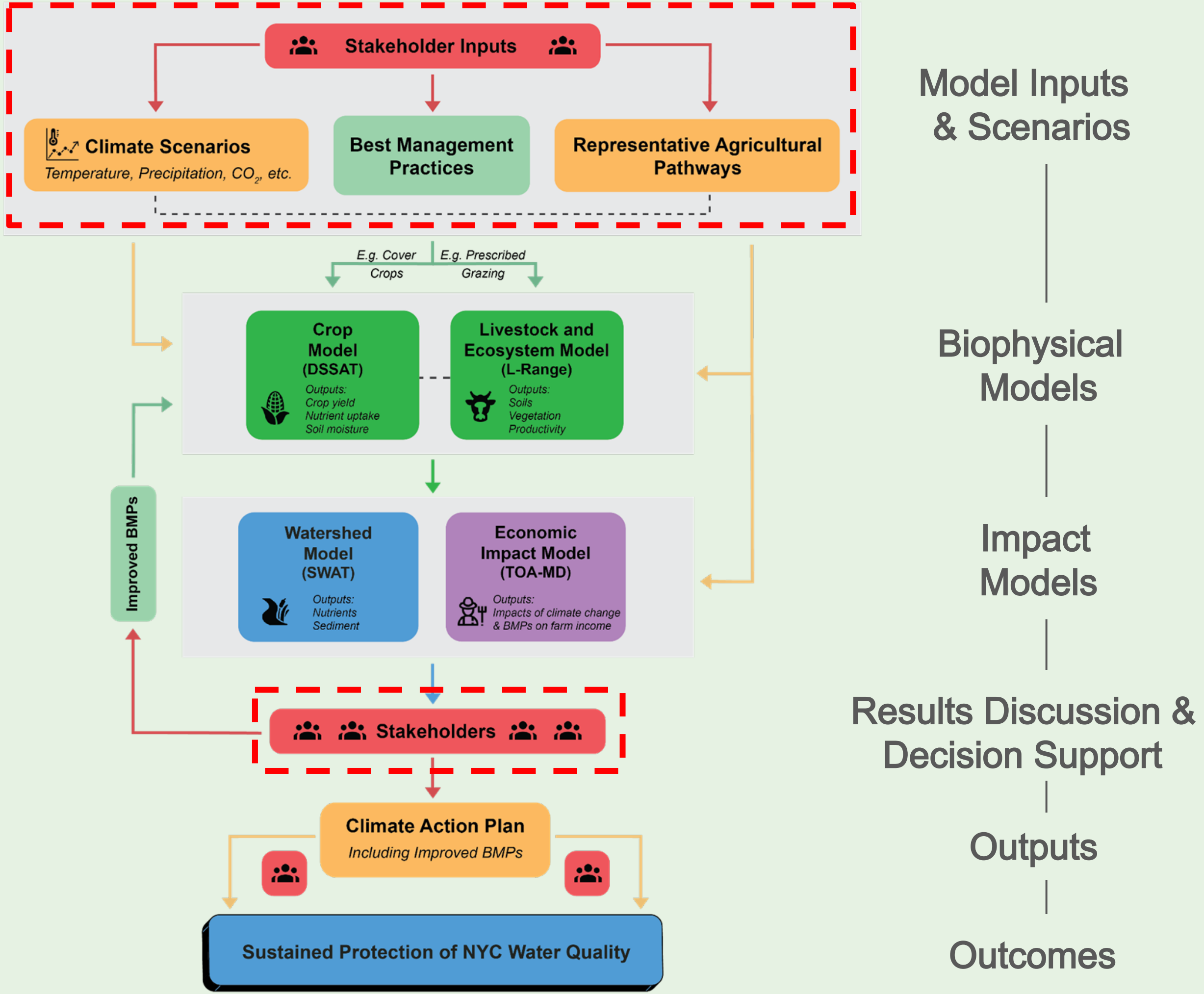

**Climate change** impacts to water quality are mediated both by **changes in land use and how they are managed**

Land use and land cover will shift due to **biogenic and anthropogenic factors**, which are impacted by **climate change, socioeconomic factors and their interaction**

**Management decisions (e.g., BMPs) will shift** due to climate change, socioeconomic factors and their interactions

**Climate change** impacts need to be understood in terms of both **long -term patterns and changes in extreme events**

# Stakeholder Engagement



# Project Models and Data

## Models

- SWAT Soil and Water Assessment Tool
  - Watershed Hydrology
  - Integrating model
- L-Range
  - Ecosystem Dynamics
  - Livestock Productivity
- DSSAT Decision Support System for Agrotechnology Transfer
  - Crop Productivity
- TOA-MD Trade -off Analysis - Minimum Dataset
  - Microeconomics
  - Adoption rates

## Data

- Topography
- Soils
- Climate
- Agricultural productivity
  - Crops, Livestock, Dairy
- Water Quality Observations (DEP)
- BMP implementation data (WAC)
- Remote -sensing data (MODIS & LANDSAT)
  - Productivity
  - Evapotranspiration
  - Land use/Land cover
- Coded transcripts from farmer focus groups
- Economic data from census and project partners
  - Direct costs and benefits of BMP implementation
  - Indirect costs and benefits of BMP implementation
  - Whole farm costs and revenue

# Focus Group Discussions – Current Conditions

## Discussions

Farmers

Agricultural experts

- Watershed Agricultural Council
- Cornell Cooperative Extension
- Delaware County SWCD
- NRCS, USDA
- Farm Service Agency, USDA

## Goals

- Learn about the farming context
  - General conditions within which the farms are operating
  - Benefits of and challenges to BMPs
  - Main concerns for the future
- Provide inputs and feedback to the modelers
- Interpret model results
- Collaborate on recommendations for improving the BMPs

# Representative Agricultural Pathways RAPS Future Scenario Development

RAPs Session
Year 2 Workshop, November 2024

## RAP 1 – Strengthening the Dairy Farms

*Increase in dairy farms supported by progressive policies and sustainable farming practices*

## RAP 2 – Transitions in Dairy-Beef Farming

*Beef farming dominates due to favorable land-use policies, strategic investments, and technological and culinary advances*

*Co-developed scenarios with local farmers and stakeholders to better represent key regional economic, social, and political impact drivers in modeling process*

*Roberto Valdivia and John Antle*

# Discussion Takeaways – Current BMP Implementation

**Benefits to the farm**

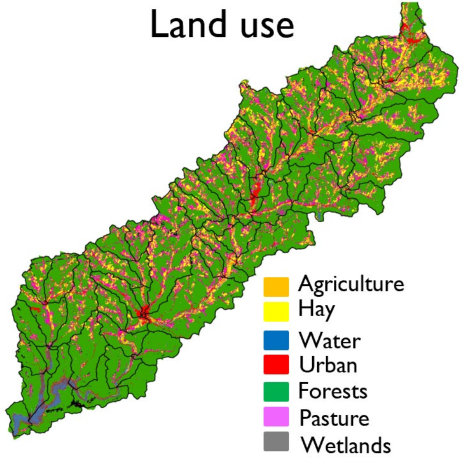
- Reduced input costs
  - Fertilizer
  - Feed
- Productivity
  - Herd health
  - Soil health
- Clean water
- Aesthetic and pride
- How aware are farmers of benefits?

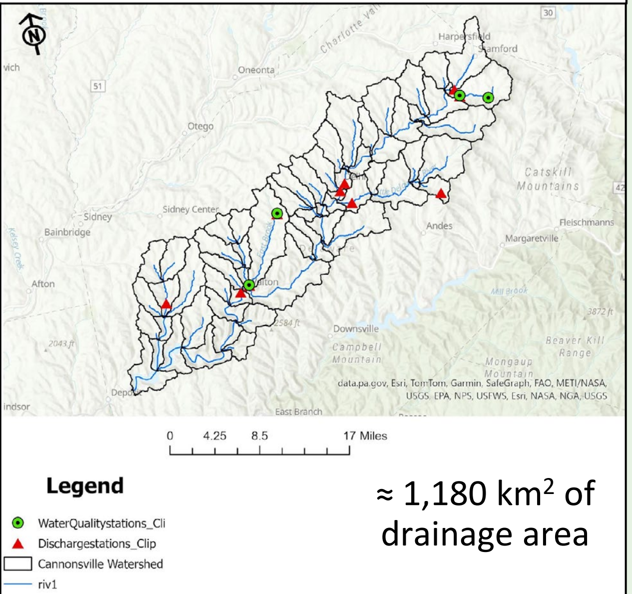
**Challenges of implementation**

- Labor hours
  - Difficult to hire labor
- Complexity of decisions
  - Sensitivity of BMP implementation to weather
  - Changing seasonal patterns - unpredictability
  - More complex management
- Maintenance of equipment and structures and input costs (fuel, fertilizer)
- Loss of land to riparian buffers
- Restrictions on use of chemicals – weeds, invasive species

# Study Area and Inputs to L-Range and SWAT Models

Land use



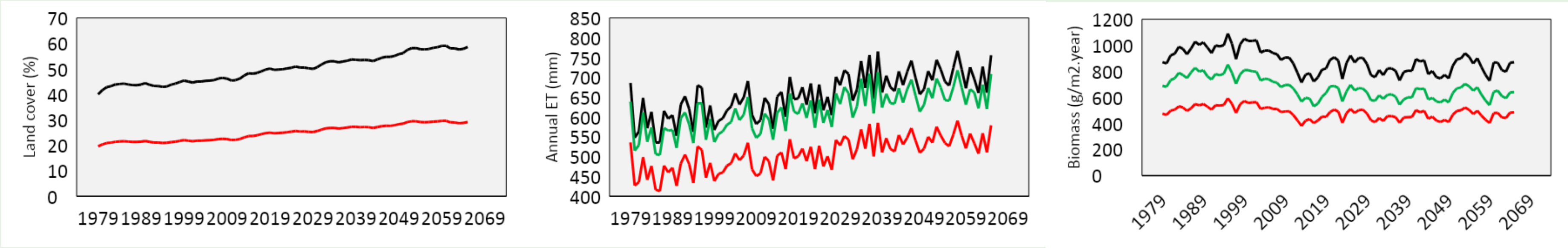

≈ 1,180 km$^2$ of drainage area

| Land use | % Cover - 2001 | % Cover - 2019 | % Change |
|---|---|---|---|
| Urban | 4.6% | 5.3% | 0.7% |
| Forests | 71.8% | 72% | 0.2% |
| Wetlands | 1% | 1.2% | 0.2% |
| Herbaceous | 0.4% | 1.3% | 0.9% |
| Open Water | 1.4% | 1.6% | 0.2% |
| Barren Land | 0.4% | 0.2% | -0.2% |
| Hay/Pasture | 19.9% | 18.1% | -1.8% |
| Cultivated Crops | 0.4% | 0.4% | 0% |

*Henrique Haas, Randy Boone, Greg Kiker*

# Impacts of climate change on vegetation growth and productivity (1980-2065)

*L-Range Preliminary Results*




Deciduous forest    Mixed forest    Hay/Pasture

*Increases in forest land cover due to increases in $CO_2$ and T and P*

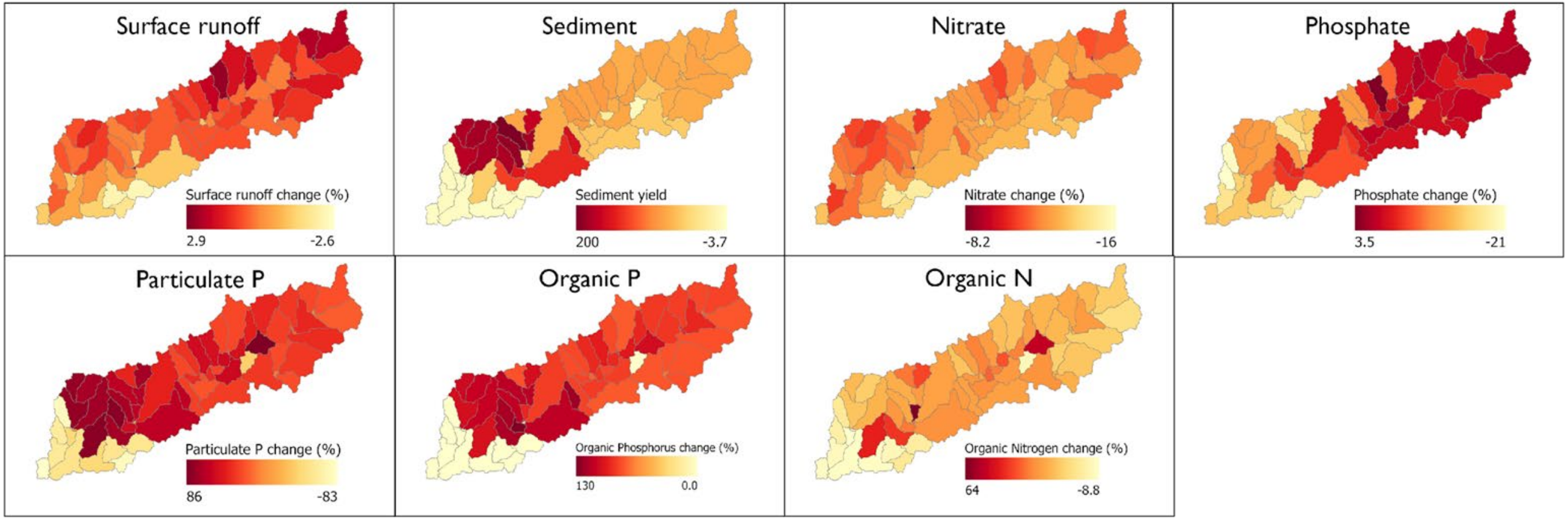
*Increases in ET due to greater influence of high T*

*Not much change in biomass due to high ET*



*Henrique Haas, Randy Boone, Greg Kiker*

# Preliminary climate vulnerability maps *(high-emissions)*



# Scenarios

CCA Scenarios represent model combinations for long-term climate change, extreme events, representative agricultural pathways, land use/land cover and BMP packages in current and future conditions

| Scenario Code | Year | Climate | Land Use (RAPS) | BMP | Extreme Events | Land Cover (L-Range) |
|---|---|---|---|---|---|---|
| H.R0.B0.N | 1990-2019 | Modeled Historical (SSP1-2.6) | RAPS 0 | BMP 0 | N | Modeled Historical (L-Range) |
| H.R0.B1.N | 1990-2019 | Modeled Historical (SSP1-2.6) | RAPS 0 | BMP 1 | N | Modeled Historical (L-Range) |
| H.R0.B2.N | 1990-2019 | Modeled Historical (SSP1-2.6) | RAPS 0 | BMP 2 | N | Modeled Historical (L-Range) |
| H.R0.B0.Y | 1990-2019 | Modeled Historical (SSP1-2.6) | RAPS 0 | BMP 0 | Y | Modeled Historical (L-Range) |
| H.R0.B1.Y | 1990-2019 | Modeled Historical (SSP1-2.6) | RAPS 0 | BMP 1 | Y | Modeled Historical (L-Range) |
| H.R0.B2.Y | 1990-2019 | Modeled Historical (SSP1-2.6) | RAPS 0 | BMP 2 | Y | Modeled Historical (L-Range) |
| F1.R0.B0.N | 2035-2064 | Modeled SSP1-2.6 | RAPS 0 | BMP 0 | N | Modeled Future (L-Range) |
| F1.R0.B1.N | 2035-2064 | Modeled SSP1-2.6 | RAPS 0 | BMP 1 | N | Modeled Future (L-Range) |
| F1.R0.B2.N | 2035-2064 | Modeled SSP1-2.6 | RAPS 0 | BMP 2 | N | Modeled Future (L-Range) |
| F1.R1.B0.N | 2035-2064 | Modeled SSP1-2.6 | RAPS 1 | BMP 0 | N | Modeled Future (L-Range) |
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| F1.R1.B2.N | 2035-2064 | Modeled SSP1-2.6 | RAPS 1 | BMP 2 | N | Modeled Future (L-Range) |
| F1.R2.B0.N | 2035-2064 | Modeled SSP1-2.6 | RAPS 2 | BMP 0 | N | Modeled Future (L-Range) |
| F1.R2.B1.N | 2035-2064 | Modeled SSP1-2.6 | RAPS 2 | BMP 1 | N | Modeled Future (L-Range) |
| F1.R2.B2.N | 2035-2064 | Modeled SSP1-2.6 | RAPS 2 | BMP 2 | N | Modeled Future (L-Range) |
| F2.R0.B0.N | 2035-2064 | Modeled SSP3-7.0 | RAPS 0 | BMP 0 | N | Modeled Future (L-Range) |
| F2.R0.B1.N | 2035-2064 | Modeled SSP3-7.0 | RAPS 0 | BMP 1 | N | Modeled Future (L-Range) |
| F2.R0.B2.N | 2035-2064 | Modeled SSP3-7.0 | RAPS 0 | BMP 2 | N | Modeled Future (L-Range) |
| F2.R1.B0.N | 2035-2064 | Modeled SSP3-7.0 | RAPS 1 | BMP 0 | N | Modeled Future (L-Range) |
| F2.R1.B1.N | 2035-2064 | Modeled SSP3-7.0 | RAPS 1 | BMP 1 | N | Modeled Future (L-Range) |
| F2.R1.B2.N | 2035-2064 | Modeled SSP3-7.0 | RAPS 1 | BMP 2 | N | Modeled Future (L-Range) |
| F2.R2.B0.N | 2035-2064 | Modeled SSP3-7.0 | RAPS 2 | BMP 0 | N | Modeled Future (L-Range) |
| F2.R2.B1.N | 2035-2064 | Modeled SSP3-7.0 | RAPS 2 | BMP 1 | N | Modeled Future (L-Range) |
| F2.R2.B2.N | 2035-2064 | Modeled SSP3-7.0 | RAPS 2 | BMP 2 | N | Modeled Future (L-Range) |

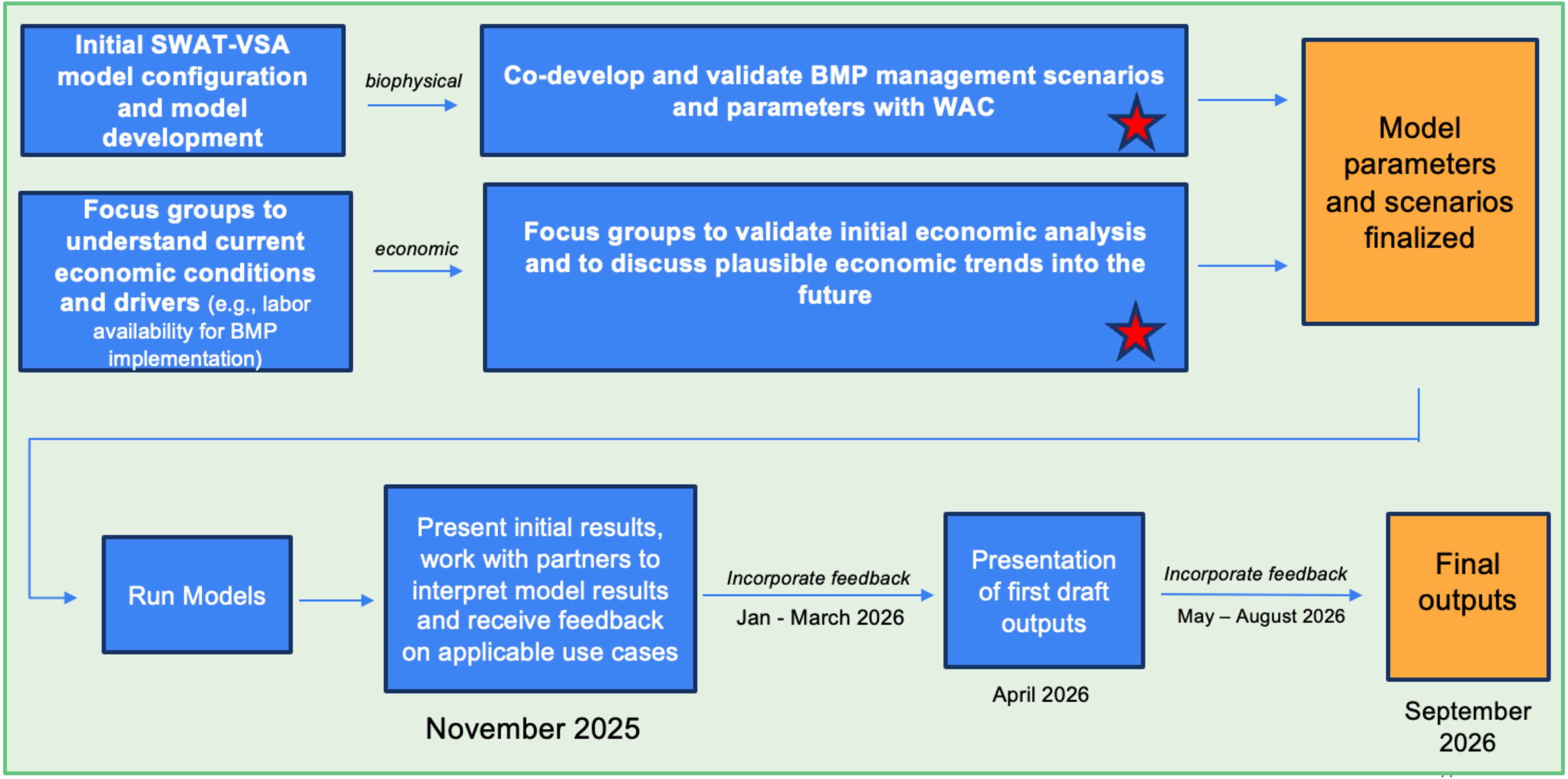
# Summary

Examine 27 future scenarios

- Three climate projections (historical, SSP1-2.6, SSP3-7.0),
- Three future land use narratives (current conditions, strengthened dairy, dairy-to-beef transitions), and
- Three best management practice (BMP) intensities (baseline, resource-constrained, and non-constrained).

- For each scenario, we derive specific parameter values directly from stakeholder input, ensuring that the model reflects on-the-ground realities.

# Where we are to date



# Economic Modeling

## Types of data we are collecting and hope to validate with WAC/farmers

- Feed, fertilizer, seed, fuel, labor, utility costs etc.
- Costs of BMP implementation, maintenance and repair (total and those only covered by farmer)
- BMP payments and cost -share made by WAC/USDA
- Historical trends in production costs and farm returns over time
- Broken down by production system and farm size
- We can do some of this from county level census data but it won't be as useful as focused engagement

## Types of questions we can answer with sufficient data

- One example scenario: production costs increase significantly (e.g., feed production is impacted by bad weather, people need to buy in more feed at a time when feed costs are high)
- How may an sharp increase in production costs impact BMP implementation rates?
- If negatively, which BMPs are most likely to not be implemented first?
- What increases in BMP payments or cost - share would be necessary to keep implementation rates at their current levels or higher?

# Biophysical Modeling

## Types of data we are collecting and hope validate with WAC/farmers

- Average amount of annual grazing days, barnyard days, manure spreading frequencies, amounts, locations
- Typical time of year for field prep, tillage methods, how much no -till vs. tillage
- Typical cover crop species and timing of planting, percent of acreage in cover crops
- Typical grazing setback from watercourses, typical size of planted riparian buffer, typical amount of watercourse with planted buffer
- Broken down by farm type and farm size, as well as management scenario: full implementation, partial implementation, weak implementation.
- We can do this with literature but it won't be as useful as focused engagement

## Types of questions we can answer with sufficient data

- One example scenario: high amount of warming in the 2050s leads to increases in short -term droughts, punctuated by extreme precipitation events
- How would the existing suite of BMPs fare to protect water quality under such a season if either fully, partially or weakly implemented?
- What changes to existing BMPs could potentially mitigate those issues?
- Which BMPs have the greatest potential to address water quality issues in this scenario?

# Products we aim to deliver

## Tools and Data

- GIS software package with new data layers (such as climate scenarios) that can be updated, tweaked and utilized by WAC staff going forward
- A report on potential improvements that can be made to existing farm ranking system based on the GIS software packages
- New, more specific and accurate SWAT-VSA model parameters that can help DEP SWAT modelers (including machine learning configurations)
- Maps of the most hydrologically vulnerable sub-basins in the Cannonsville Reservoir basin under various climate and management scenarios
- Figures of notable climatic changes likely to occur in the regional (e.g., shifts in seasonality, changes in nighttime temperatures, snowmelt, etc.)

## Papers and Reports

- Paper on anticipated changes in vegetation dynamics in the watershed under climate change, and resulting impact on hydrology
- SWAT-Machine Learning paper (multi-model assessment of hydrological impacts under climate change)
- Co-developed paper on BMP effectiveness under a variety of future management and climate scenarios
- Co-developed paper on economic modeling of BMP adoption rates under various economic scenarios
- Co-developed “Climate Action Plan” report, including responses to recommendations from the NASEM report
- Paper on anticipated changes to hay, pasture and dairy productivity under climate change

# Next Steps

1. **Complete co-development of beneficial management practices** (BMP) “packages”

1. **Test BMP packages in L-Range, SWAT, and TOA-MD models under current and future scenarios** to project impacts on farmer livelihoods and other key outputs

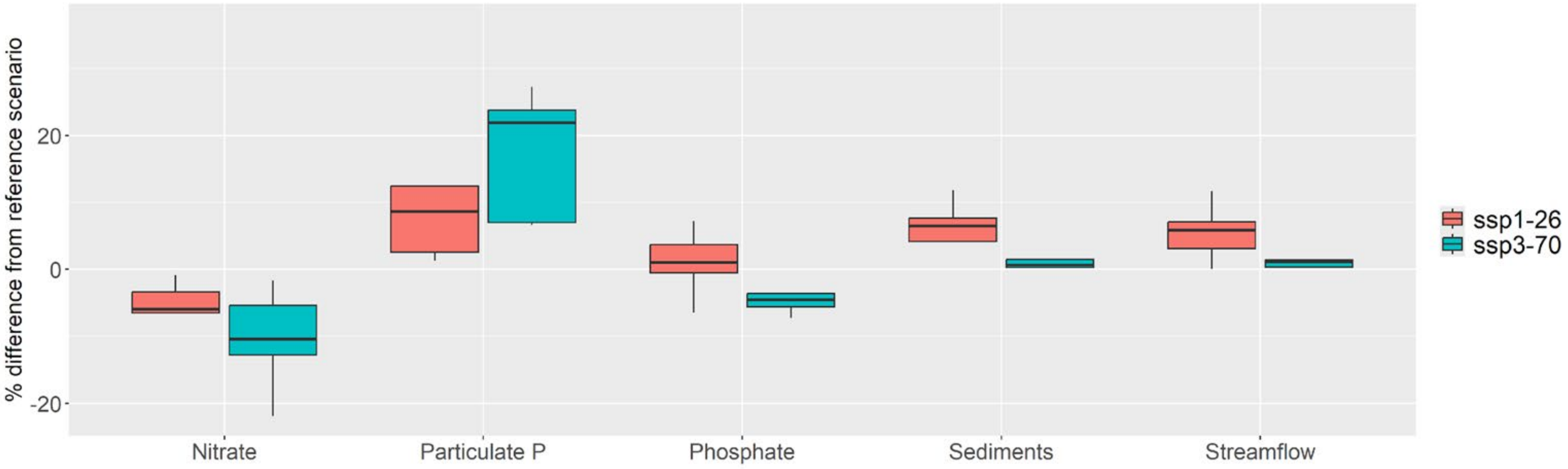
2. **Develop BMP Prioritization Tool** including climate vulnerability maps

3. **Synthesize findings for NYC DEP Climate Action Plan**

# Discussion

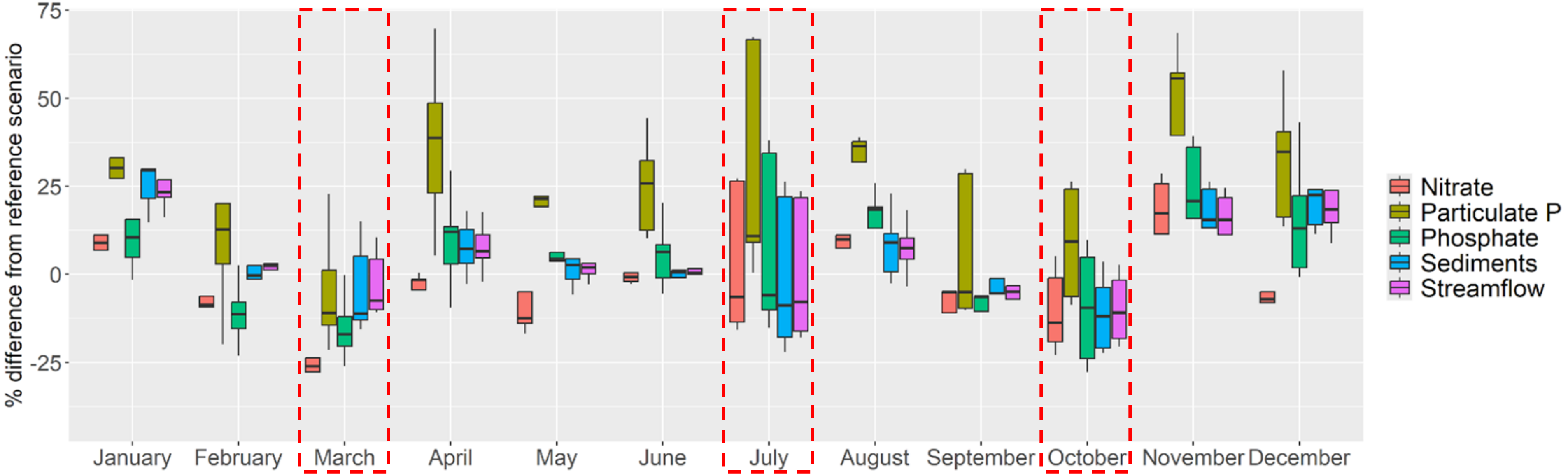
# Preliminary long-term climate change:
# *Mean annual discharge and loadings*

Historical period (1985–2020) vs.
Future period (2030–2065) — Low and High Emissions Scenarios



# Preliminary long-term climate change:
# *Mean monthly discharge and loadings (low-emissions)*

Historical period (1985-2020) vs.
Future period (2030-2065)— Low Emissions Scenarios



# Preliminary climate-induced vegetation changes