Project Overview: Impacts of Climate Change on the Phenology of Linked Agriculture-Water Systems

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Overarching Hypothesis

Climate-induced adaptive changes in agricultural practices and ecosystem processes will cause large indirect phenologic (seasonal and intra-annual) effects in riverine loading that will propagate through watersheds to the estuary and affect ecosystem health.

Chesapeake Bay System Study Site

- Deep central channel with seasonal (summer) stratification.
- Large watershed to estuarine surface area ratio (~15:1).
- Increasing agricultural yields and development during the last 60 years.
- >50-years of monitoring data and >30-years of intense modeling effort in watershed and estuary; U.S EPA enforced TMDL activity since 2010.

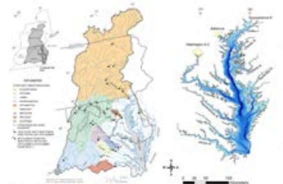


Figure 1. The Chesapeake Bay watershed and major tributaries (left) and estuary (right).

1. Farmer Adaptations to Climate Change.

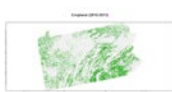
CC/LU Scenarios

How is farmer crop choice changing with climate?

- Discrete choice modeling using climatic, environmental, and economic factors.
- Analyzing climatic thresholds for double cropping systems.
- Developing methods for "big data" econometric analysis.
- Allowing for farm structural change.

How are farmers altering timing of activities to manage risk?

- Crop yield modeling with varying sensitivities to weather shocks throughout growing season.
- Simulating alternative planting decisions (and subsequent fertilization timing).
- Combining timing and crop choice decisions to predict changes in nutrients available to run off.



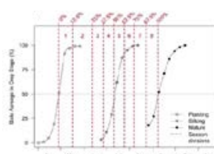


Figure 2. Simulation of crop choice (upper panel) and timing of crop development (right panel).

2. Watershed Processes Affecting the Phenology of Connectivity.

CC/LU Scenarios

Motivation question
How do changes in climate and land use affect the timing and magnitude of water, N, P and SS loads reaching the Bay?

Key science question
How do key, poorly understood watershed processes influence inter- and intra-annual transport dynamics?

Lag times

- Using age-rank StorAge Selection (rSAS) functions to better represent lags in stream response to nutrient loading from groundwater.

Variable source areas

- Using TOPOSWAT to simulate the influence of VSAs on inter-annual variability of nutrient transport.

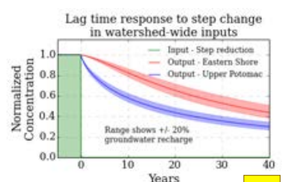


Figure 3. Using transit time models to study groundwater transport lag as a function of changes in recharge. Includes data courtesy of Ward Sanford, USGS.

3. Water Quality Outcomes in the Estuary.

How do changes in the timing and location of watershed inputs affect estuary physical and biological responses, including the severity of hypoxia?

Analyzing 30-year Bay monitoring dataset for chlorophyll, dissolved oxygen, and nutrients to understand shifts in the seasonal cycles.

Conducting simulations using ROMS-RCA to understand the impacts of alternative loading seasonality and pulsed nutrient inputs on oxygen criteria failure, which will link to economics team.

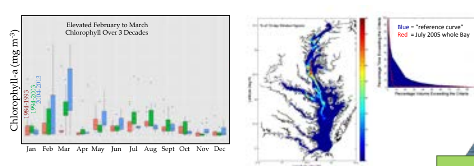


Figure 4. Seasonal cycles of chlorophyll-a over each of the past three decades show changes in intra-annual variability (upper left panel). Simulated oxygen distribution in July and associated cumulative frequency diagram to assess criteria (upper right panel).

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4. Adaptive Policy Instrument Evaluation.

Identify policy-relevant leading indicators of environmental harm.

- Finding combinations of human actions and biophysical system responses that generate economic harms.
- Identifying the type, timing and scale of nutrient reduction interventions that avoid adverse conditions, e.g.:
  - Post-drought actions to capture unused nutrients
  - Payments for changes in tile drain management contingent upon rainfall patterns.

Create rapid-response (state-contingent) policy tools to adaptively manage environmental risk.

- Computing the optimal interventions - where marginal cost of pollution reduction equals marginal damage cost of pollution delivered.
- Simulating adoption of policy instruments using risk-adjusted profit expectations and heterogeneous producers.
- Evaluating cost-effectiveness of dynamic instruments under likely adoption scenarios.

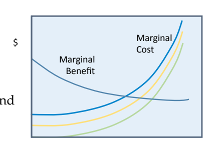

Figure 5. Considering policy costs and benefits.

CC/LU Scenarios

Climate Change and Land Use (CC/LU) Scenarios

- Forcing scenarios with a common set of climate and land use scenarios representing plausible conditions up to 2100.
- Deriving climate scenarios from downscaled and bias-corrected CMIP global circulation models.
- Land use scenarios being made by partners using the Chesapeake Bay Land Change Model.

Close Integration with Bay Management Activities

- Working closely with Chesapeake Bay Program Office (USEPA, USGS, NOAA) in support of Chesapeake Bay Program partnership.
- Helping improve the Chesapeake Bay Modeling System (toward 2017 and 2022 TMDL USEPA deadlines).
- Running workshops and symposia in collaboration with the Chesapeake Research Consortium.

Educational Outreach

Hosting a school teacher to develop an educational module for the Teach Ocean Website. (www.teachoceanscience.net).

Acknowledgements

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