



# Modeling Effects of Human Decision-Making on Lakes in Coupled Human Natural Systems

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## INTRODUCTION

- Humans benefit greatly from the ecosystem services provided by freshwaters.
- However, human activities also degrade water quality, which can generate incentive for behavioral change.
- Here, we provide an overview of a new collaborative NSF-funded project (CNH-Lakes) that integrates multiple disciplines to study how GLEON lakes and human decision-making feedback to affect water quality.

## OBJECTIVE

- Characterize, quantify, and contrast feedbacks between human and natural systems in lake catchments.



**Figure 1.** Water quality and human decision-making are driven by the dynamic interactions among and between human and natural systems within lake catchments.

## RESEARCH QUESTIONS

- How do human land-use decisions interact with catchment biophysical characteristics to influence the effects of nutrient loading on lake water quality?
- What are the essential management variables (EMVs) in coupled lake-catchment systems and at what temporal resolution must those variables be measured to detect feedbacks from natural to human systems?
- How does collective action affect land-use decision-making and policies at the local, catchment, and state levels to alter nutrient loading and impact lake water quality?
- What are the key generalizations that can be derived from the focal catchments to understand how water quality and human activity are linked at the regional to continental scale?

## STUDY SITES

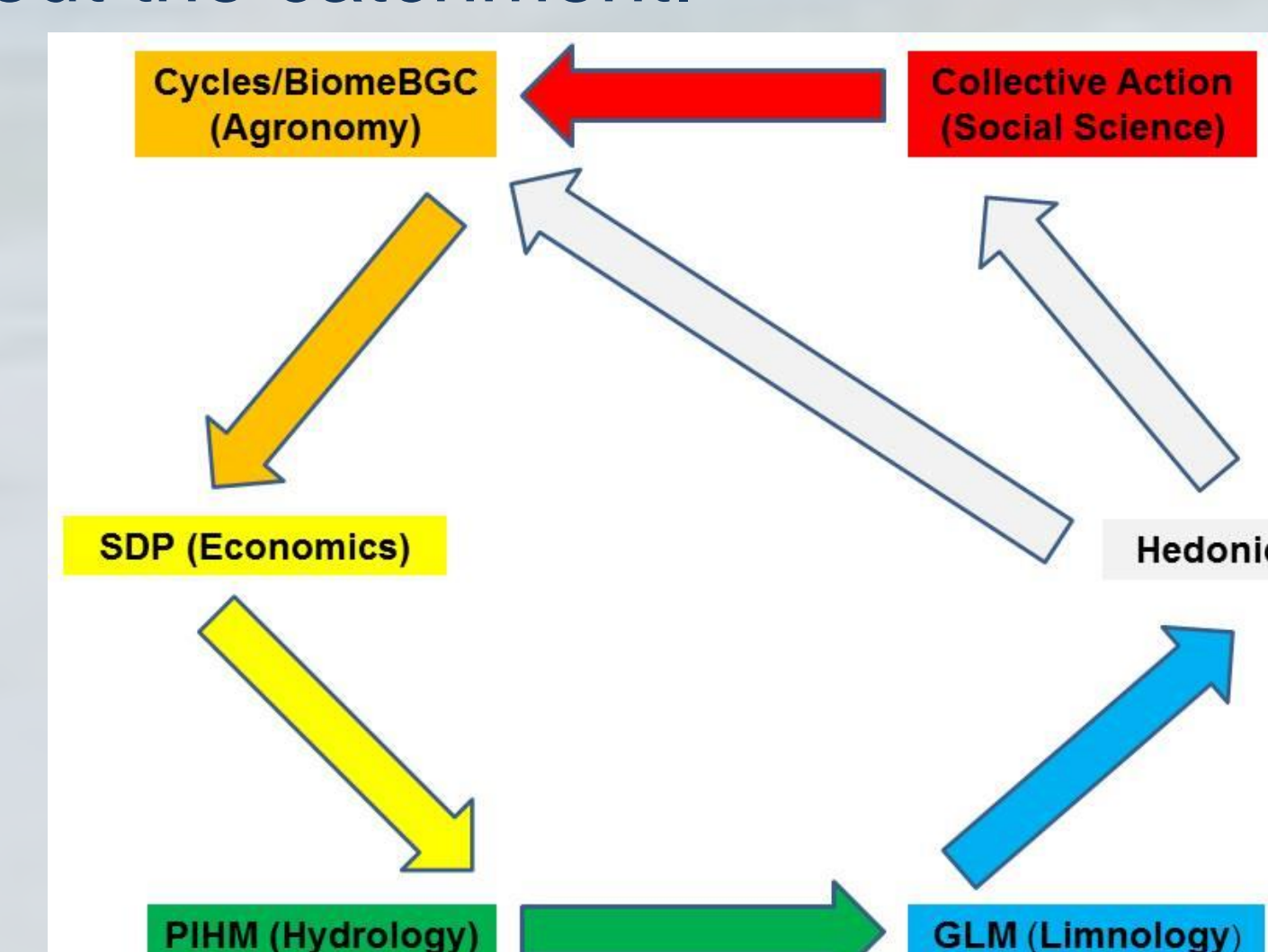
- The CNH-Lakes project examines the linkages between land use, lake water quality, and local communities in three contrasting lake systems in the United States.
- This yields underlying mechanisms and EMVs for CNH lake systems, which allows scaling-up and extrapolating model results to thousands of US lake catchments.

**Table 1.** CNH study sites (Lake Sunapee, New Hampshire, Oneida Lake, New York, Lake Mendota, Wisconsin, USA)

	Sunapee, NH	Oneida, NY	Mendota, WI
Trophic State	Oligotrophic	Mesotrophic	Eutrophic
Land Use	81% Forest 8% Developed 4% Agriculture	47% Forest 33% Agriculture 13% Developed	55% Agriculture 20% Developed 1% Forest
Lake Association	Water Quality	Fisheries	Algal Blooms
Dominant Focus			

## COUPLED MODEL FRAMEWORK

- Cycles/BiomeBGC provides site-specific nutrient and water fluxes that influence crop yields, which is coupled to an economic model (SDP) of land and nutrient use decisions.
- This yields spatial and temporal information about agricultural production and nutrient applications, which feeds into PIHM.
- PIHM translates producer decisions into nutrient loads, which are converted by the hydrodynamic-ecological GLM model into changes in lake water quality.
- The GLM output feeds into the hedonic property value model.
- Changing property values influence collective action by lake associations, which influences land-use decisions throughout the catchment.



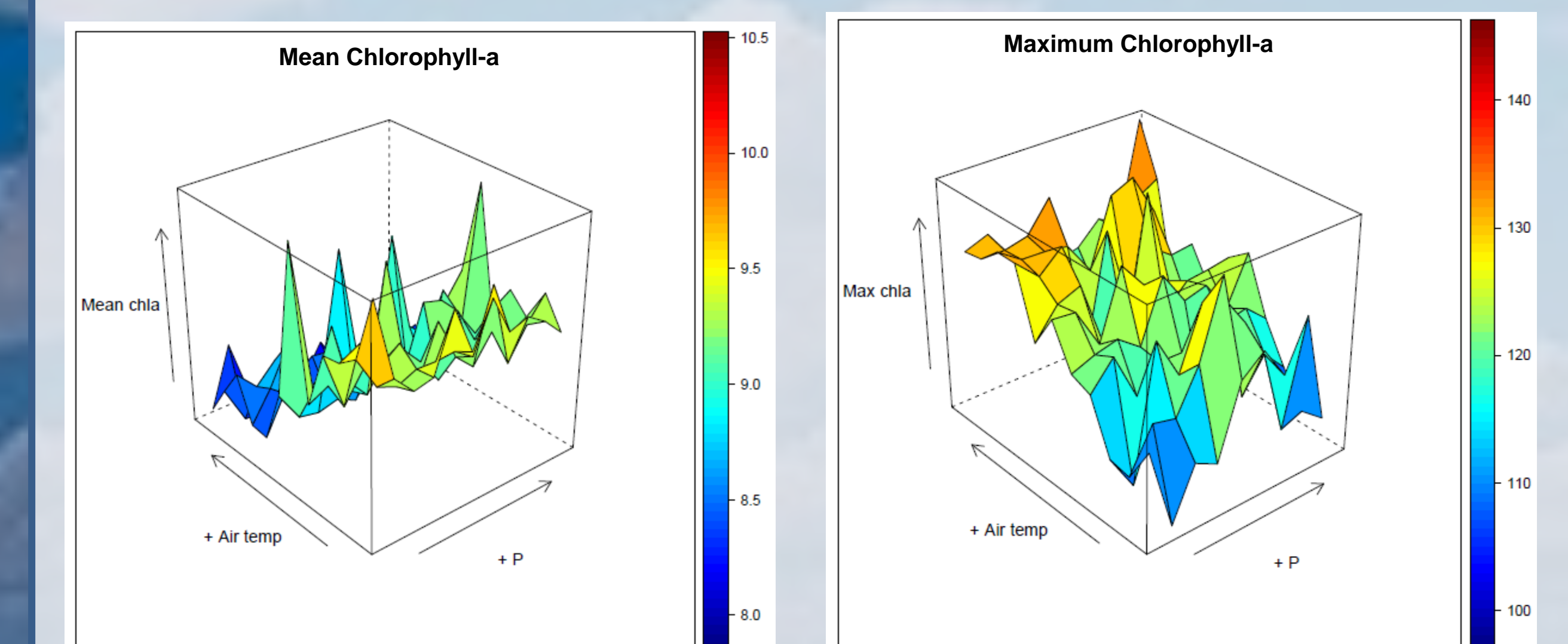
**Figure 2.** CNH coupled model framework including models and data flows

**GRAPLER** (GLEON Research and PRAGMA Lake Expedition; [grapple.org](http://grapple.org))

- Distributed computing system, which integrates and applies overlay virtual network, high-throughput computing, and Web service technologies
- Leverage new distributed computing capacity to efficiently run millions of GLM simulations for the three GLEON lakes
- Understand interactive effects of land use and climate change on water quality

## PRELIMINARY RESULTS

- The efficiency of running tens of thousands of simulations reveals the nonlinearity of climate change and land use change interactions.



**Figure 3.** Mean and maximum chl-a change with increasing phosphorus and air temperature

## CNH TEAM

- >20 Researchers; >6 Disciplines; >8 Institutions



**Figure 4.** May 17-19, 2016 Annual CNH Workshop at Mountain Lake Lodge, Virginia, USA

## ACKNOWLEDGEMENTS

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