Biodiversity and climatic controls of New York State's economy – lessons from Sugar Maples

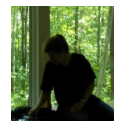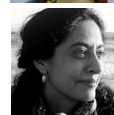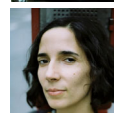| Faculty Name	Expertise Critical in Project (up to 2)
Ana Carnaval (Team Lead)	A. Integrative biology.
	B. Climatic controls of species distributions and genetic diversity.
Michael Hickerson	A. Population genetics.
	B. Barcode data in ecology and evolution
Kyle McDonald	A. Remote sensing technology and applications.
	B. Drone photogrammetry.
Andrew Reinmann	A. Plant (maple) physiology.
	B. Plant responses to changes in snowpack.
Jean Krasno	A. Environmental Policy.
	B. Negotiation processes.
Rebecca Albee	A. Photography.
Emily Raboteau	A. Creative Writing.
	B. Climate Change Communication.
Michelle Valadares	A. Creative Writing.
	B. Film- and documentary- making.

BIO

EAS

GEO

POLICY

ART

ENGL

Projected maple syrup (L/tap)

Framing Question

How do soil microbes and climate
impact New York State's maple-related industries
through sap production and Fall foliage colors?

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Problem Statement:
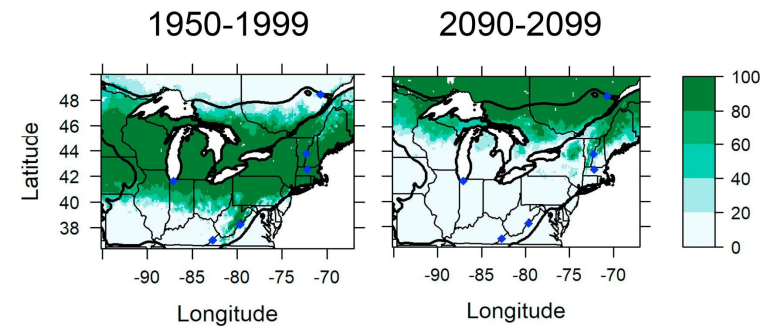
- Climate and habitat change threaten biodiversity and the ecological services it provides.

- As such, they directly impact economies and human well-being worldwide.

- Shifting the global economic paradigm and the market forces that keep altering our planet's climate and natural resources requires changes in human perception, values, and behavior.

- To set this paradigm shift in motion, we must act locally and engage scientists, political scientists, artists, writers, students, and a diverse community of stakeholders.

Objectives

We will use one staple of New York State's economy – sugar maple trees (*Acer saccharum*) and the maple-related industries – to:

Objective 1

Quantify and model how biodiversity (soil microbiota) and climate impact the state's economy through effects on

- Maple sap production and composition (multi-million dollar maple syrup industry),
- Fall foliage tourism (through impact on maple leaf color)

Objective 2

Engage maple syrup producers in data collection, analysis and discussion.

Objective 3

Combine scientific measurements with photography and story-telling to reach out to general public and stakeholders, to promote change in perception, value, and management

Objective 4

Engage CCNY students from multiple schools in data collection, analysis and discussion, by

- bringing groups of mixed disciplines to the field
- creating new interdisciplinary courses on campus
- adding hands-on training to curricula in Biology, Earth and Atmospheric Sciences, Political Science and English.

Intellectual Merits and Broader Impacts

- **Intellectual Merits**
  1. Integrate environmental, physiological, and genetic data to uncover how climate and soil biodiversity impact Maple sap production, sap quality, and Fall foliage.
  2. Use statistical analyses and models to identify actions to help ensure the persistence of sugar maple trees and the industries they support.
  3. Establish a pilot program to study and facilitate adaptation to climate change.

- **Broader Impacts**
  1. Foster change in the public perception of global warming and the value of biodiversity.
  2. Create hands-on, problem-based, cross-disciplinary training on campus, having students and faculty from multiple schools work together for a common goal.

Technical Approach

| Years 1 and 2 | Data Collection: Joint field trips Discipline-based bench analyses | Years 2 and 3 | Data integration | Years 2 and 3 | Data sharing, outreach |
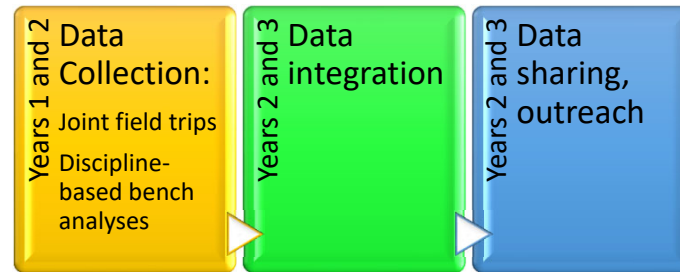
Approach 1: Joint field data collection (years 1 and 2)

1. Characterize temperature, precipitation and snowpack in 10 maple stands across different soil types and climates in the state of NY

2. Document leaf colors through chemical analysis, drones and artistic photography (Fall)

3. Characterize sap flow and composition (sugar content; Late Winter/Early Spring)

4. Describe soil microbiota through eDNA barcoding: composition and diversity of bacteria and fungi (across seasons)

5. Interview local sugaring communities: practices, relevant policies, narratives, challenges

6. Involve CCNY students in field collection or lab-based analysis: Biodiversity, Climate Change and the Political Process (BIO/SUS/IR), Creative Writing (ENG), Intro do Biotechnology Lab (BIO), Environmental DNA (BIO), new FIQWS course in yr. 2

- **Approach 2: Data integration (years 2 and 3)**
    1. Identify statistical relationships between climate and soil microbe biodiversity with maple sap flow, sugar concentration, and leaf color vibrancy
    2. Explore and develop correlative and mechanistic models to predict impacts of future climate change given ongoing tendencies and alternative scenarios
    3. Integrate scientific and social science research to identify policies that can facilitate climate change adaptation or mitigation
    4. Involve CCNY students in integrative lab-based analysis: Biodiversity, Climate Change and the Political Process (BIO/SUS/IR), Capstone Project (SUS), Environmental Project (EAS), new FIQWS course

- **Approach 3: Public Outreach**
    1. Hold all-hands-on-deck workshop in partnership with the Appalachian Mountain Club to:

    a. Report back to maple producers, share findings and strategies, delineate local policy proposals

    b. Lead a nature exploration retreat to CCNY students

    2. Organize public exhibit to showcase our creative writing pieces, art, scientific findings, policy, and management recommendations

Team Milestones

Goals	Fall YR1	Win YR1	Spr YR1	Fall YR2	Win YR2	Spr YR2	Fall YR3	Win YR3	Spr YR3
Definitions of field sites	X			X					
Environmental data collection (sensors and drones)	X	X	X	X	X	X			
Collection of soil samples for environmental DNA	X	X	X	X	X	X			
Collection of leaves for pigment analysis	X			X					
Collection of sap flow data		X			X				
Collection of sap samples for sugar analysis		X	X		X	X			
Interviews with producers and community	X	X	X	X	X	X			
Artistic photographic documentation	X	X	X	X	X	X			
DNA analysis of soil and plant genetic diversity	X	X	X	X	X	X			
Remote sensing data acquisition and processing	X	X	X	X	X	X			
Chemical processing of leaf pigment analysis	X	X		X	X				
Chemical characterization of sap (sugar content)		X	X		X	X			
Integration of field and remote sensing data	X	X	X	X	X	X			
Collection of snowpack & soil frost data		X			X				
Analysis of snowpack & soil frost data		X	X	X	X	X			
Collection of sap flow data			X			X			
Analysis of sap flow data			X	X	X	X			
Integration of science databases					X	X	X	X	
Final report by political science team due						X			
Integration of scientific and policy data							X	X	X
Creative writing piece due								X	
Photograph and illustrative art pieces due								X	
Biodiv., Climate Change and the Political Process	X						X		
Climate Writing course	X						X		
Intro do Biotechnology Lab course		X							
FIQWS course planning					X				
FIQWS course is offered						X			
Environmental DNA course						X			
Capstone Project and *Environmental Project* courses				X			X		
Appalachian Mountain Club Meeting and Retreat									X
Joint exhibit									X

Team Qualifications

Environmental sampling and monitoring

- **Documentation of climate, vegetation and soil freeze-thaw processes**. McDonald has extensive experience with satellite remote sensing (satellites, aircraft and aerial drones). Previous studies included collaborations with Carnaval and Hickerson.

Plant physiology

- **Collection of vegetation physiological data.** McDonald validates remote sensing data with in situ vegetation physiology (including sap flux and soil frost dynamics). Reinmann has extensive studies of plant responses to changes in snowpack in New England.

- **Sap Composition Analysis.** Reinmann has existing collaborations to guide sap sugar characterization in house.

- **Photosynthetic and Physiological analysis of Sugar Maples.** Reinmann has work experience with this species in the northern US and has an established network of sugar maple producers to collaborate on this project.

DNA data analysis

- **Population genetics and analysis of DNA barcode data.** Hickerson and Carnaval have extensive experience collecting and analyzing DNA data from animals, plants, fungi and bacteria and will collaborate on molecular characterizations of sugar maples and their associated soil microbiota.

Political Science

- **Environmental Policy and Negotiations**. Krasno researches and teaches topics related to Environmental Policy and Negotiations on campus, including a course co-listed with Carnaval (Biodiversity, Climate Change, and the Political Process). Both collaborate on an Interdisciplinary Grant on Agricultural Production and Biodiversity Conservation trade-offs.

Creative Expression

- **Photography.** Albee has extensive experience in photography, also working with other media such as sculpture, video, and performance.

- **Creative Writing**. Raboteau leads CCNY's Climate Writing class and is a leader in climate change communication. Valladares has experience in film- and documentary-making and will use an ongoing collaboration with the Appalachian Mountain Club to organize a nature exploration retreat to CCNY students in conjunction with our grant reporting activities.

Team Qualifications

Management Plan

- Monthly meetings (in hybrid mode) for decision-making, updates, review of milestones, group learning, networking. All faculty and involved postdocs and students.

- Community agreement jointly drafted on first meeting to ensure respectful, inclusive, and friendly environment.

- Non-faculty members to elect two representatives to reach out to PI in case of any conflicts. PI mediates conflict resolution.

- Core Team (all faculty, science postdoc, and one student per faculty) work together in the field: 6 joint field expeditions (2-3 days) across years 1 and 2. Group bonding.

- Slack workspace to provide organized, dedicated communication channel and alerts. Email function to included members who are unfamiliar.

- Dropbox to store and share common use files.

Future Funding Prospects and Self-Sustaining Plan

Convergence-focused grants through NSF (Carnaval lead)
- Biodiversity on a Changing Planet
- Critical Aspects of Sustainability
- Organismal Responses to Climate Change
- Dynamics of Integrated Social-Environmental Systems

NASA (McDonald lead)
- Biodiversity and Ecological Forecasting Program
- Applied Sciences Program

USDA NIFA (Reinmann lead)

Monthly project meetings include dedicated time discuss new proposals

Expansion ideas in place: Maple adaptive genomics, science data meet economic growth models