The City College of New York
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CCNY College-wide Research Vision (CRV) Initiative Concept White Paper

The Sugar Maple Project: Integrating Science, Society, and Stakeholders to Advance Climate Resilience

Project Team:

Principal Investigator:
Dr. Ana Carnaval, Associate Professor

Department:
Department of Biology, Division of Science, The City College of New York

Other Key Personnel:

CO-PIs:

- Dr. Michael Hickerson (Department of Biology, Division of Science, CCNY)
- Dr. Kyle McDonald (Department of Earth and Atmospheric Sciences, Division of Science, and The Grove School of Engineering, CCNY)
- Dr. Andrew Reinmann (Department of Geography and Environmental Science, Hunter College, and CUNY Advanced Science Research Center)
- Dr. Jean Krasno (Department of Political Science, Director of MA Program in International Relations, The Colin Powell School for Civic and Global Leadership, CCNY)
- Emily Raboteau, M.F.A (Department of English, Division of Humanities & the Arts, CCNY),
- Michelle Valadares, M.F.A (Department of English, Director of MFA Program in Creative Writing, Division of Humanities & the Arts, CCNY)
- Rebecca Albee (Chair, Department of Art, Division of Humanities & the Arts, CCNY)

External Collaborator

- Peter Gregg (Maple Sugar Producer, founder of The Maple News and The Maple Trader)

Stakeholder Groups to be invited to collaborate:

- White Oak Farm, New York
- New Leaf Tree Syrups
- Maple Research Group, University of Cornell
- Procter Maple Sugar Research at University of Vermont
- Baskin Sugar Works, New Hampshire
- Vermont Sugar Makers Association
- Passamaquoddy Maple, Maine

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Project Concept Description: (Maximum 2 pages)

Keywords: Global Warming, Sugar Maples, range shifts, bioeconomy, New England

Objective: Climate change threatens the health of both the ecosystems and economy of New York State. Through measurements and models that link genetic diversity and ecosystem function, we will develop a new understanding of the impacts of climate change on sugar maple trees and the enormous ecological, economic, and cultural services they provide, while simultaneously fostering change in the public perception of global warming and the value of biodiversity. We will combine new and existing data on the distribution, physiology, and genomics of sugar maples and engage stakeholders to improve management practices and help ensure the persistence of sugar maple trees (and the industries they support) and facilitate adaptation to climate change. By building a narrative around its unique leaf shape and colors, and its ecological and economic services, we will liaise multiple CCNY schools, publish our findings via scientific papers and in the popular media, inspire through art, identify effective policy language, and create new collaborative courses on campus.

Approach: Our team has expertise in biodiversity modeling and population genomics (Hickerson and Carnaval), engineering, remote sensing, and environmental science (McDonald), ecophysiology and forest ecology (Reinmann), political science (Krasno), climate change communication (Raboteau), creative writing and film-making (Valladares), and art (Albee). This multi-disciplinary group will ensure that our science stays grounded, understandable, relevant and applicable beyond academia. We will 1) combine tree physiological observations (photosynthesis, rooting habit, sap flow and composition; Reinmann), descriptions of ecologically important freeze-thaw processes during the sugaring season (collected via remote sensing; McDonald), and genomic characterizations (Hickerson, Carnaval) into sugar maple range models; 2) identify how industry practices and policies can be changed to facilitate persistence and adaptation (Krasno); 3) measure fall leaf color change (Reinmann), contrast them with soil eDNA samples describing microbial associations (Hickerson), genomic information (Carnaval), and local environmental conditions and sap flow (McDonald); and 4) share findings with stakeholders and the public through narrative journalism (Raboteau) and art (Albee). A 5) FIQWS course will expose CCNY students to the issues and tools of the project (Carnaval). An 6) MSc/upper undergraduate-level course will train students to sample and barcode the soil microbial community of sugar maple stands and explore correlations with the environment, leaf color variation, and genetics (Hickerson). Retreats with the Appalachian Mountain Club will 7) promote connection and expression through writing and art (Valladares).

Outcomes: Carnaval, Hickerson, Reinmann and McDonald will work across departments to generate predictive models of sugar maple response to future climate scenarios that incorporate not only persistence and extinction probabilities, but also adaptation. The team will also elucidate environmental and genetic drivers of leaf color change and sap composition dynamics and investigate correlations between climatic conditions and mycorrhizal and microbial associations in the soil. A collaboration between Krasno and the scientists will identify stakeholder practices and policy change that can facilitate adaptive responses to climate change. Raboteau, Valladares, Albee, Krasno will lead our team as we share our findings with the industry and government and promote public awareness of (and personal involvement with) New York's biodiversity. The project will create a FIQWS course, a field-based, biodiversity informatics course, and exploration and self-expression retreats to connect students across departments and to nature. It will also contribute to Raboteau's ongoing MFA Climate Writing class.

Expected Products: Carnaval and Hickerson have modeled species ranges and genetic diversity under future climates, but not yet incorporated processes of biological adaptation. Reinmann has collected photosynthetic and physiological data on sugar maples, but not analyzed them through the lens of genetics and evolution.

McDonald has used satellite remote sensing to document vegetation and soil freeze-thaw processes, but has yet to apply these measures in this species. Approaches 1 and 3 will result in at least two high-impact collaborative peer-reviewed publications that combine our expertise and inform biodiversity science, the government, and the industry. By exploring associations between genetic variants and climatic conditions, we will publish a list of candidate genes for climate adaptation in sugar maples that advances fundamental science and the design of future experiments relevant to conservation and the industry. Approaches 2 and 4 will allow the Humanities, Arts, Policy and Science to collaborate and identify ways to meaningfully reach out to the public and stakeholders; this will be a new experience for all PIs. With students from Hickerson's data-driven course, we will write an article about the environmental and genetic determinants of color change in sugar maples (approach 3). Raboteau, Valladares and Albee will lead us and our students through public essay writing and artistic experiences to change the public's perception about biodiversity and climate change. FQWIS will allow us to understand each other's vocabulary and hopefully attract new faculty and departments to our group.

Merits: The crucial ecological, economic, and cultural roles of sugar maples are tightly associated with climate**.** This shade-tolerant species is limited to cool, moist climates. As such, sugar maples are widespread across the northeast quarter of the U.S., and found in the forests of nearly every county in the NY state[1]. With low winter air temperatures supporting sugar formation in sap, syrup production depends on sap flow prior to the start of the growing season. This early season sap flow is the result of physiological processes that occur during the late winter and early spring (the sugaring season). Above-freezing temperatures during the day lead to positive pressure in the tree, causing the sap to move from the roots towards the tree canopy; spiles inserted into the stem allows a portion of this sap to be diverted out for syrup production. At night, below-freezing temperatures draw water into the tree through the roots, replenishing sap in the tree and allowing sap to flow the next day[3]. The timing and vibrancy of the fall leaf senescence process are also influenced by environmental conditions but vary across individuals[4], implicating a possible genetic component. Anthropogenic climate change, evident across the U.S. and in the New York State, is already impacting the ecological, economical, and social roles of sugar maples: accelerated warming trends are leading to longer frost-free seasons, declines in winter snowpack, and changes in the timing and duration of the sugaring season, which damage sugar maple roots and reduces tree productivity[5]. Projected changes in climate are expected to have large negative effects on the sugar maple population in New York[5]. To meet 2012 production, the state is expected to make up for 0.6 million taps in the near future[6]. However, it remains uncertain whether genetic differences across populations, adaptive capacity within individuals, or interactions with the soil biome provide mechanisms to cope with warming temperatures, declining winter snowpack and increasing soil frost. By gathering experts in the sciences, the maple industry, policy and expression, we will answer these questions.

Impact: As the New York State tree, sugar maple (*Acer saccharum*) is an iconic representative of its biodiversity. This highly abundant long-lived tree species makes important contributions to water quality and the carbon cycle, and directly interacts with local populations of mammals, birds, insects, and fungi as a major food source and habitat[7]. Sugar maples also constitute one of the most economically and culturally valuable hardwood trees in the Northeast. Not only maple timber continues to be increasingly explored in construction and for furniture, but maple sap, boiled into syrup and sugar, supports a multi-million-dollar industry: the State of New York is the second largest producer of maple syrup in the U.S., which, just in 2019, reached a value of $142 million[8]. Moreover, sugar maple leaves have an economic value of their own, as their stunning bright gold and red fall colors contribute to the state's phenomenal fall foliage and support a large tourism industry drawing visitors from around the world. Lastly, sugar maples have a rich cultural legacy. They have been a main source of sweetener, timber, and medicine for multiple indigenous groups, and used in gatherings to praise the passage of time and the seasons[9]. They played a fascinating role in the history of the abolitionist movement in the U.S.[10] Last, but not least, their shape and colors, along with maple syrup production, give the millions of people surrounded by north temperate forests a sense of place and time, and heritage.

Milestones:

Months 1-6: Gather genetic, environmental, ecological, and soil microbiome data. Develop drone flight tests and in-situ spectral analyses to explore their use in leaf color assessments. Establish in situ stations for monitoring temperature and sap flow. Establish remote sensing data processing and analysis flow. Gather sugar maple-related policy practices in place, drawing on local knowledge. Launch FIQWS and Division of Science courses.

Months 7-9: Make scientific datasets interoperable; feed them into preliminary models of physiology, sap yield, range and genetic diversity. Promote Appalachian Mountain Club retreats and artistic interpretations. Initiate directed narrative journalism project.

Months 9-12: Share and discuss draft of our narrative journalism piece and drafts of scientific papers. Lead stakeholder day-event. Submission of annual technical report. Organize art exposition. Discuss Year-1 results and Year-2 development plan with program officer.

Budget – TOTAL: $199,320

Personnel Costs: SUB TOTAL: $159,060

Key Personnel: We request 1 month of Summer Salary ($12,000) to support co-PI Raboteau as she interviews and researches for the narrative journalism piece for Orion Magazine, writes and edits the text.

Research staff: We request $75,060 to hire a full-time postdoc who will liaise the scientific data across departments and labs and help the team coordinate the efforts of data gathering and integration (amount includes fringe).

Administration staff: The team does not require administration staff.

Students:

- **Ph.D.** We request 6 months of funding to support a Ph.D. student to assist Carnaval and Hickerson with the sugar maple genomic analyses ($20,000). We also request 6 months of support for a Ph.D. or Masters-level student to support McDonald and Reinmann with remote sensing and aerial drone data collections analyses, sap flow analyses, collection and analysis of ground validation data, and integration of these data within the larger ecological and biological context of this effort ($20,000)
- **MFA.** We request 6 months of funding to support an MFA student to assist Albee photographing in the field, conducting research, and with the production of artwork in the studio and darkroom ($20,000).
- **MA.** We request 4 months of funding to support an MA student in the Political Science program assisting Krasno with interviews and policy studies ($12,000).

OTPS Costs: SUB-TOTAL: $40,260

We request support (total: $4,300) for the physiological work in sugar maple stands led by Reinmann. It includes LICOR equipment calibration ($1,500), consumables for root work, sap flow and sap composition analyses ($2,800).

We request $10,000 to cover field work costs. It includes $2,000/site x 4 sites ($8,000 total) to obtain air and soil temperature sensors across stands, sap flow sensors and data loggers and $2,000 to support team field trips to deploy stations and collect data (8 trips at $250 each).

We request $14,500 in consumables and genome-scale sequencing services to extract DNA, develop a genomic library, and genotype 190 individual sugar maple trees from throughout the range of the species (two extraction plates at $250 each, library development and sequencing of two 96-sample plates).

For the soil microbial community DNA barcoding course (course title: eDNANY), we request $4,460 for the purchase of 30 CALeDNA kits for each matriculated student, and associated field work costs. The kits will be used in the semester-long undergraduate course focusing on metabarcode DNA sampling of maple stand soils, which will generate data for the project while educating students in the Division of Science. The current cost is 20 (students) x $223.00 (per kit), plus $1,000 for transportation and food for sampling days.

We request $5,000 for consumables and services for production of artwork (Albee). This includes supplies and services for photographing, darkroom and digital printing, and framing: 35mm & 120 film ($500) Eco Pro photographic chemicals ($300), photographic paper/printing ($1000), and framing services- Gerald Kurian-Kurian & Co/Frame & Display ($3200).

We request $1,000 to be paid as honoraria to Peter Gregg, a maple sugar producer, founder and writer of The Maple News and The Maple Trader, who will join our group in our field trips and assist us as we understand producer practices and engage and communicate with stakeholders. Mr. Gregg has professional links with Co-PI Reinmann.

We request support for a day-long reporting and outreach event at the end of the year to bring together a variety of stakeholders and brainstorm next steps (maximum 20 people, potential venues are Black Rock Forest or Appalachian Mountain Club). Funds will be used to help transport the group and to cover for lodging and food ($1,000). No additional funds are needed for the nature retreat, as the MFA Program already has support to promote it through the Appalachian Mountain Club.

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