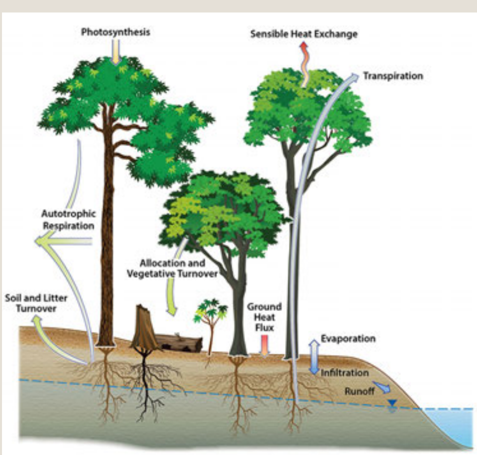
Next-Generation Ecosystem Experiments–Tropics

ngee-tropics.lbl.gov

Advancing predictive understanding of how tropical forest ecosystems will respond to climatic and atmospheric change

Tropical forests cycle more carbon and water than any other ecosystem, and they play critical roles in determining Earth's energy balance. Additionally, intact tropical forests are estimated to be Earth's largest carbon sink, yet the processes controlling tropical forest carbon cycling are not well established. Understanding of carbon and related water and energy exchanges between tropical forests and the atmosphere lags that of other ecosystems, and poor model representation of these processes is the most significant source of terrestrial uncertainty in climate projections. To address these challenges, the Terrestrial Ecosystem Science (TES) program within the Department of Energy's (DOE) Office of Biological and Environmental Research (BER) is supporting a next-generation ecosystem experiments project in the tropics (NGEE–Tropics).

The NGEE approach seeks to improve the representation of critical ecosystem processes in Earth system models (ESMs) by focusing on systems that are globally important, climatically sensitive, and understudied or inadequately represented in ESMs. In this approach, modeling and process research are closely and iteratively connected so that model structures and requirements are considered in the development of process studies whose outcomes in turn are designed to directly inform, challenge, and improve models. Ultimately, the NGEE–Tropics project will develop a representative, process-rich tropical forest ecosystem model, extending from the bedrock to the vegetative canopy-atmosphere interface. In this comprehensive approach, the evolution and feedbacks of tropical ecosystems in a changing climate can be modeled at the scale of a high-resolution ESM grid cell (e.g., less than 10-km resolution). NGEE–Tropics builds on another initiative under way in the Arctic (NGEE–Arctic), which is examining similar uncertainties facing Arctic ecosystems.



Above- and Belowground Ecosystem Measurements. *NGEE–Tropics research focuses on state-of-the-science model development and measurement activities most critical for predicting the future of the tropical forest carbon sink and associated energy and water fluxes.*

NGEE–Tropics. *The future of tropical rainforests such as the Amazon (pictured, with flux measurement tower protruding from tree canopy) is the focus of a new research project that combines field experiments and predictive modeling.*

Measurements to Inform Models

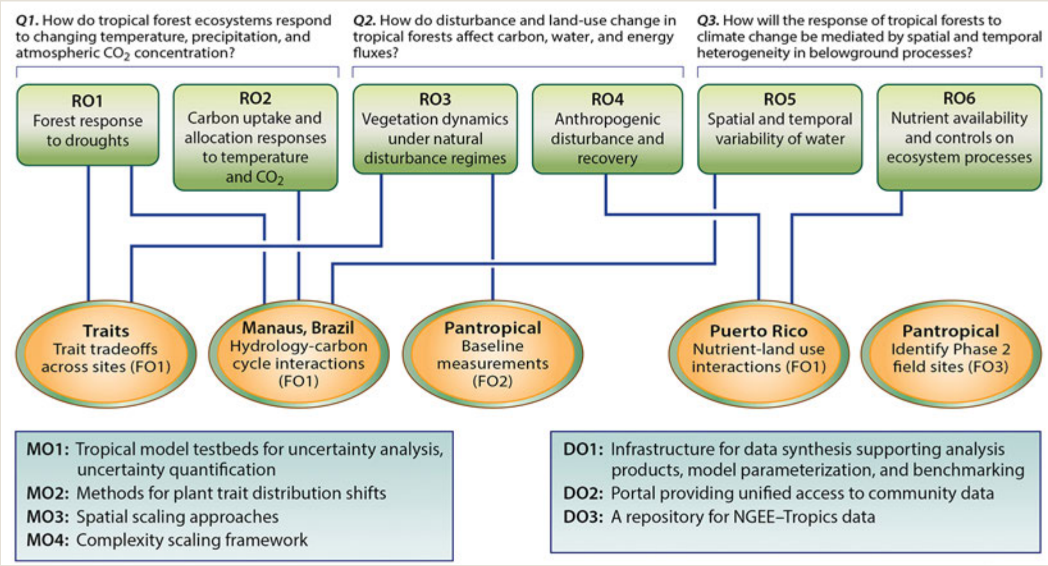
The tremendous biological diversity of tropical forests presents a special challenge for modeling. A critical question is whether these forests will continue to offset a large fraction of anthropogenic carbon emissions in the 21st century or become carbon sources.

During the first phase of the 10-year NGEE–Tropics project, researchers will assess what is known about tropical forest ecosystems and how well these processes are represented in models. Several initial field studies are being developed at key sites and globally across the tropics. Pilot studies in Brazil, Panama, and Puerto Rico will link modeling advances with field observations. Measurements at these sites are designed to fill high-priority knowledge gaps and encompass investigations on (1) forest carbon cycle–hydrology interactions, (2) nutrient limitations on tropical secondary forests, (3) plant functional diversity response to climate change, and (4) regional variability in the causes of tree mortality. More information on these studies follows.

Key NGEE–Tropics Science Questions

The experiment's first two overarching science questions address the response of tropical forests to major environmental drivers of change. The third question encompasses the critical roles belowground processes play in mediating these responses.

1. How do tropical forest ecosystems respond to changing temperature, precipitation, and atmospheric carbon dioxide (CO_2) concentration?
2. How do disturbance and land-use change in tropical forests affect carbon, water, and energy fluxes?
3. How will the response of tropical forests to climate change be mediated by spatial and temporal heterogeneity in belowground processes?



Research Approach. *NGEE–Tropics research objectives (RO1–RO6, green boxes) addressing each of the overarching science questions (Q1–Q3) are directly linked to pilot studies and field objectives (F01–F03, gold circles) in Phase 1. These objectives are supported by a foundation of modeling and integration framework objectives (MO1–MO4, blue box on left) and data synthesis framework objectives (DO1–DO3, blue box on right).*

- **Forest Carbon Cycle–Hydrology Interactions:** Explore how tropical forests respond to reduced precipitation, which is expected in some tropical regions. These studies are important for understanding whether tropical forests will release carbon in response to drought instead of accumulating it.
- **Nutrient Limitations:** Investigate how soil fertility affects regrowth on abandoned agricultural lands. These so-called secondary forests are known to take up a large amount of CO_2 from the atmosphere and store it for decades, but the uptake rate is thought to depend on soil fertility.
- **Plant Functional Diversity:** Explore which traits confer resistance to specific environmental stressors. How tropical forests respond to changing climatic and atmospheric conditions will ultimately be determined by which species thrive and which are vulnerable to the new conditions.
- **Pantropical Variation in Tree Mortality:** Develop an improved mechanistic understanding of mortality agents and lay the foundation for additional investigations at a set of pantropically distributed sites. How trees succumb to mortality varies across the tropics, yet little of this regional information has been integrated into ESMs.

Results from these Phase 1 NGEE–Tropics research activities will guide both model development and additional pantropical fieldwork that will be conducted in Phases 2 and 3.

Trait-Enabled Modeling Framework

To understand the highly uncertain processes that control the tropical forest carbon balance, research must determine the suites of plant and microbial traits best adapted to thrive under changing climatic and atmospheric conditions. Consequently, the ultimate goal of the NGEE–Tropics project is to develop a transformational modeling framework that integrates biotic functional diversity with the multiscale, multicomplexity processes that control tropical forest feedbacks to the climate system. Such processes include belowground biogeochemistry, plant demography and ecophysiology, plant functional traits and tradeoffs, and aquifer-to-canopy hydrology. Model advancements will be directly enabled by pantropical syntheses of existing data and investments in high-priority observations and experiments that enhance process representation, support model parameterization, and provide critical benchmarks. These model functionalities have never before been brought together into a single platform or rigorously evaluated against observations at a pantropical scale.

Leveraging NGEE–Tropics Investments

Led by Lawrence Berkeley National Laboratory, the NGEE–Tropics project is a collaborative effort that includes scientists at Brookhaven National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Smithsonian Tropical Research Institute, U.S. Department of Agriculture's Forest Service, National Center for Atmospheric Research, and National Aeronautics and Space Administration. Additional partners include universities and other state and federal agencies, as well as institutions from other countries including Brazil's National Institute of Amazonian Research. This array of national and international collaborators will enable numerous synergistic research activities.

The NGEE–Tropics project also is leveraging key existing datasets, observations, and monitoring networks, as well as research supported by other BER and DOE programs and user facilities to assess knowledge gaps and prioritize research needs. All NGEE–Tropics data generated from observations, experiments, and models will be made available at **ngee-tropics.lbl.gov**. BER provides research funding to leverage the NGEE investment through regular Funding Opportunity Announcements posted at **www.grants.gov**.

Program Manager and Websites

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Images were provided by Lawrence Berkeley National Laboratory.