How do responses to climate change differ among ecosystem types and geographical areas?

Forest and Freshwater Ecosystem Responses to Climate Change and Variability at US LTER Sites

Citation Campbell, J.L., Driscoll, C.T., Jones, J.A., Boose, E.R., Dugan, H.A., Groffman, P.M., Jackson, C.R., Jones, J.B., Juday, G.P., Lottig, N.R., Penaluna, B.E., Ruess, R.W., Suding, K, Thompson, J.R., & Zimmerman, J.K. (2022). Forest and freshwater ecosystem responses to climate change and variability at US LTER sites. BioScience, 72(9), 851-870. https://doi.org/10.1093/biosci/biab124

How and to what degree do forest and freshwater ecosystems respond to climate change?

Freshwater systems provide services humans rely on as well as impacting associated forest systems through soil wetness and water availability. Climate change influences freshwater and forest systems because mean temperatures rise through time and because extreme weather events become more common. This study uses data from long term ecological monitoring sites with forest and freshwater components to determine the type and level of climate change and the ecosystem responses across a range of geographic zones.

How are temperature and precipitation impacted by changing climate conditions?

Mean annual air temperature increased at all sites during the period 1950 - 2019. Precipitation increased at sites in the Eastern US and one site in the West over the same period.

The number of extreme hot months increased at all sites 1980 - 2019 and extreme hot months were more frequent than extreme cold months. Relative temperature changes were greatest at the tropical site, while absolute changes in temperature were greatest at cold sites.

Do changes in temperature and precipitation impact the overall water availability in an ecosystem?

Seven of the nine LTER sites are becoming wetter as they become warmer. The two sites that are becoming drier are the only two western sites. This corresponds to other data showing that the western US climate is generally getting drier.

Streamflow is impacted by many factors and changes may not follow the same trend as SPEI. Catchment routing or active layer depth may change, or forest plants with different water requirements may become more dominant.

Summer dryness will become a bigger factor in the future, as sites are projected to become water limited during summer, especially in the West.

At most sites extreme streamflow corresponds to precipitation levels. However, some forests seem to compensate for extreme precipitation events better than others. More research is needed into the interaction between climate and disturbance history on hydrology.

What impact does climate change have on primary production and are ecosystems energy limited?

Currently all sites are energy limited during winter and are projected to remain so under future climate conditions. All sites are currently energy limited during summer, although most are drier than during winter.

Primary production generally increases with warming climate at forest or freshwater systems but other factors cause carbon loss, which can cancel out the increased productivity.

Changes in plant species, fire patterns, and other climate driven processes may create feedback loops that increase or decrease carbon in the system. Understanding these processes will be key for predicting future conditions.

Has climate change impacted the biome classification of the study sites? Are biome classifications likely to change in the future?

Current climate data for each site generally match the temperature and precipitation levels in Whittaker's classification for the current biome type. Projected data indicate that some sites will be shifted into a climate space that does not match their current biome.

Biome shifts can be caused by other factors and disturbances even when temperature and precipitation remain within the range of the current biome.

How does climate change impact inorganic nutrient cycling?

Inorganic material cycling is linked to organic material cycling and hydrology. Changes in plant species, growing season, and water cycles impact the capture or export of inorganic matter.

What other impacts does climate change have on ecosystem processes and services?

Changes in climate may make natural cycles more or less synchronous across landscapes, depending on changes in moisture availability, plant species occurrence, and animal distributions. Species assemblages may become dominated by invasive species that are better able to tolerate new conditions.

In general, climate change is lessening ecosystem services in all categories: habitat, cultural, provisioning, support. Dialogue between researchers/managers and policy makers will have increased importance.

Research Approach/Methods

The authors analyzed data from nine LTER sites representing forests that are boreal, temperate, temperate rainforest, and tropical rainforest.

They analyzed changes in temperature and precipitation over the period of LTER research relative to several reference periods covering various parts of the 20th century, as well as predicted future trends, using gridded data from public databases.

To determine if future climate warming would cause a shift in ecological classifications at LTER sites, the authors plotted historical and projected climate data for each site on Whittaker's biome classification. Projected data was from three regional and three global climate models.

They investigated changes in water processing by forest and freshwater systems by evaluating whether standardized precipitation evapotranspiration index (SPEI), a measure of climatic water balance, was related to changes in air temperature and stream flow.

The authors evaluated the dryness index, which indicates water surplus or deficit, for past conditions and projected future conditions to determine if sites would be water limited or energy limited.

They compared the frequency of high and low flow days between historical and future projected data for all sites and analyzed the data relative to precipitation.

Keywords stream, lake, climate change, ecosystem services, LTER

Images

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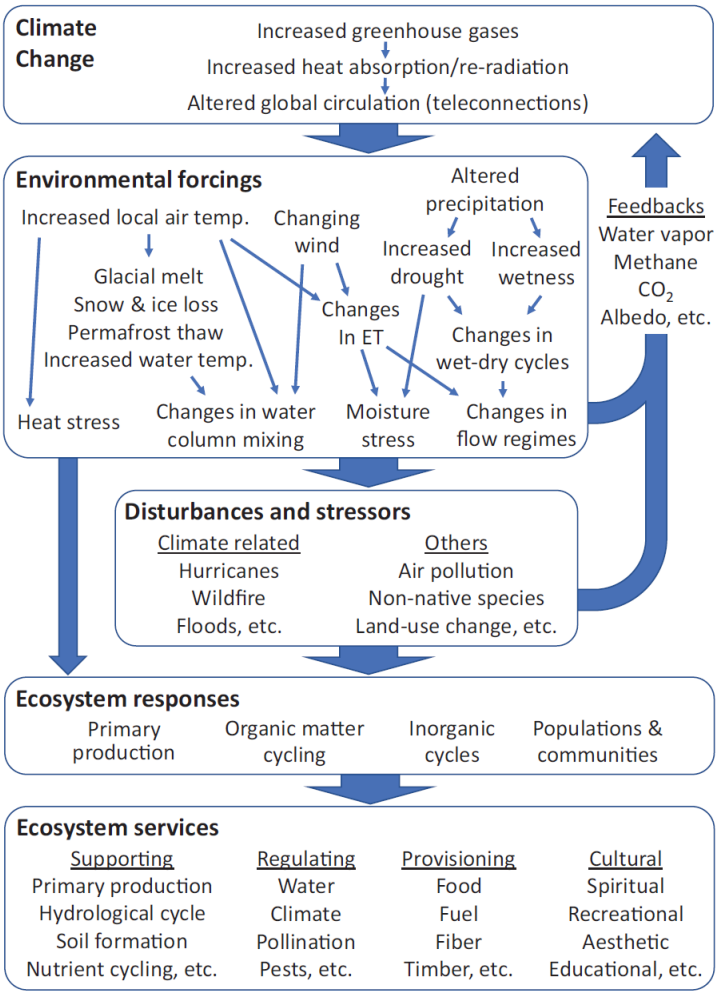

Figure 1 in Campbell et al. 2022. Conceptual diagram showing how climate change and associated ecological forcing elicit ecosystem responses and alter ecosystem services.

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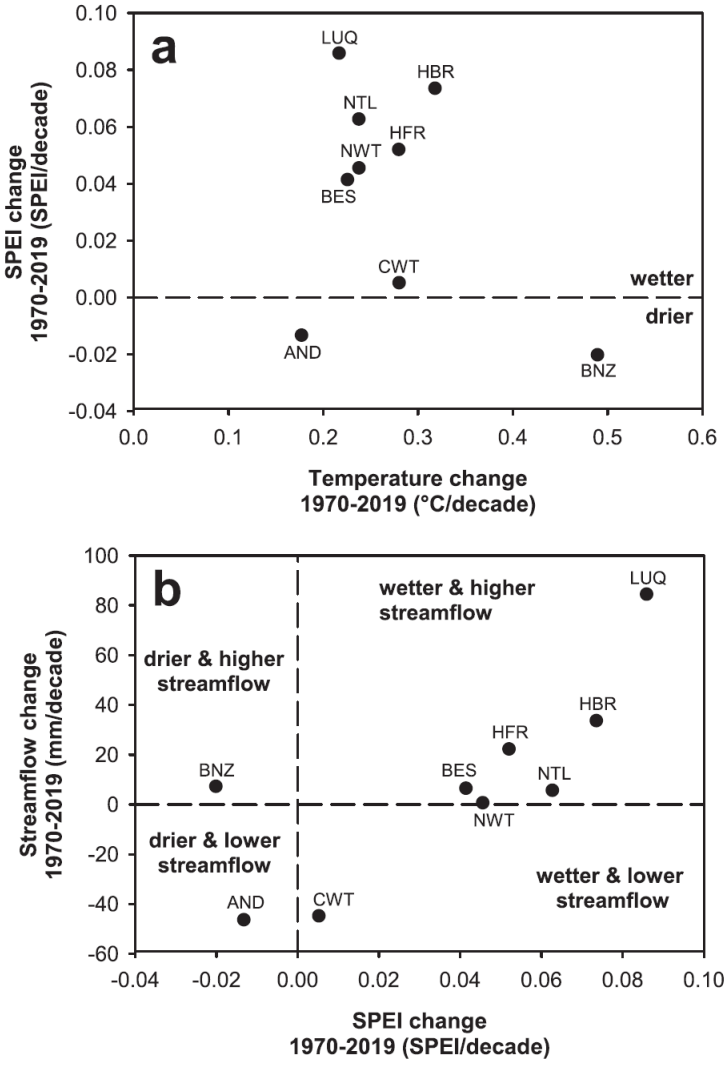

Figure 5 in Campbell et al. 2022. Trends in (a) the Standardized Precipitation Evapotranspiration (SPEI) index versus changes in air temperature and (b) streamflow versus changes in SPEI for 1970–2019. Trends in SPEI greater than zero indicate increasingly wet conditions and values less than zero indicate increasingly dry conditions.

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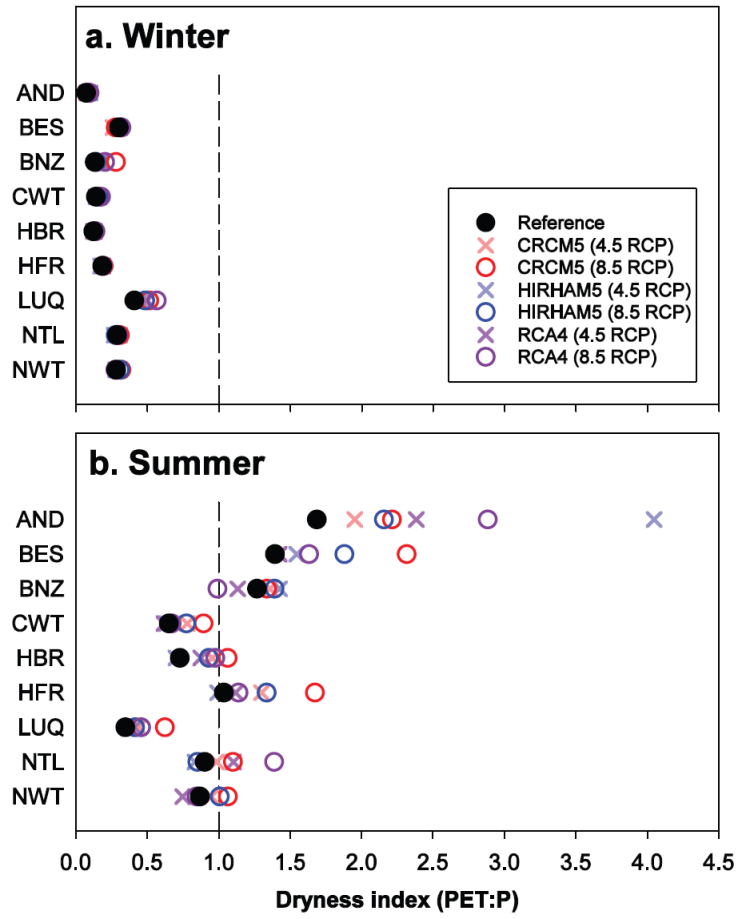

Figure 6 in Campbell et al. 2022. Dryness index calculated as the ratio of potential evapotranspiration to precipitation during (a) winter (December–February) and (b) summer (June–August) under the reference period (mean from 1990 to 2019) and future projected climate change (mean of 2070–2099) at forest and freshwater LTER sites. Values less than one (dashed line) indicate energy limitation, whereas values greater than one indicate water limitation.

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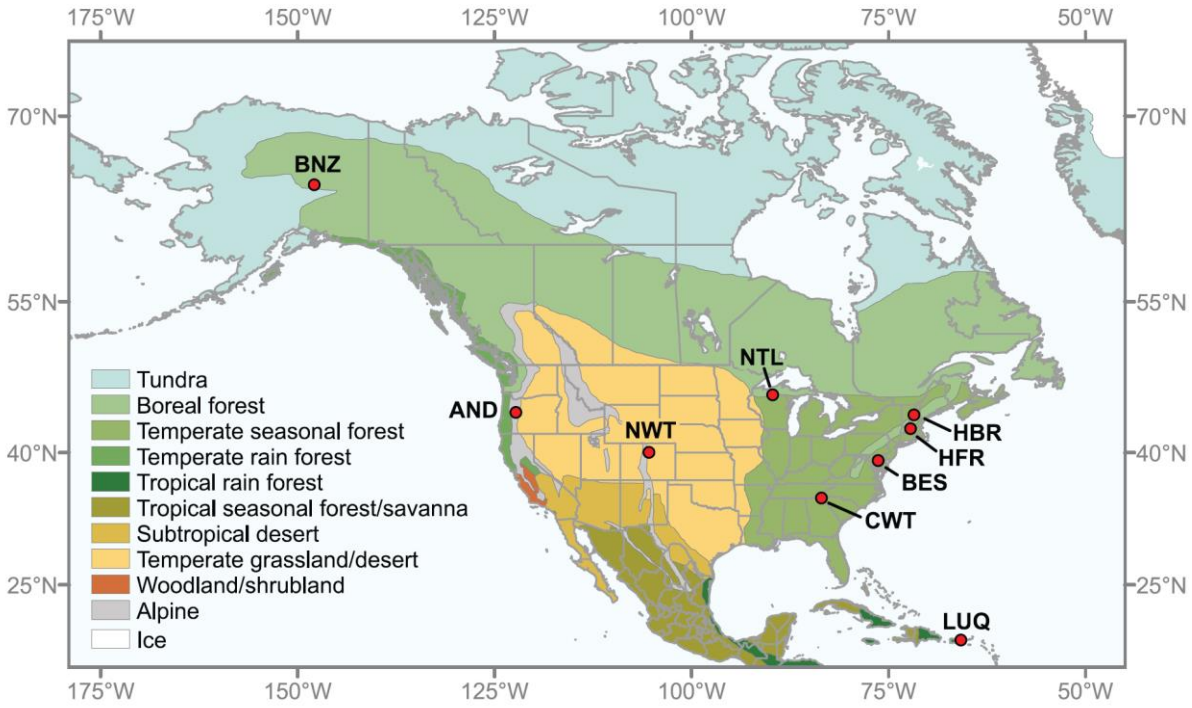

Figure 2 in Campbell et al. 2022. Study sites in the Long Term Ecological Research Network representing forest and freshwater ecosystems.