Global variations in critical drought thresholds that impact vegetation

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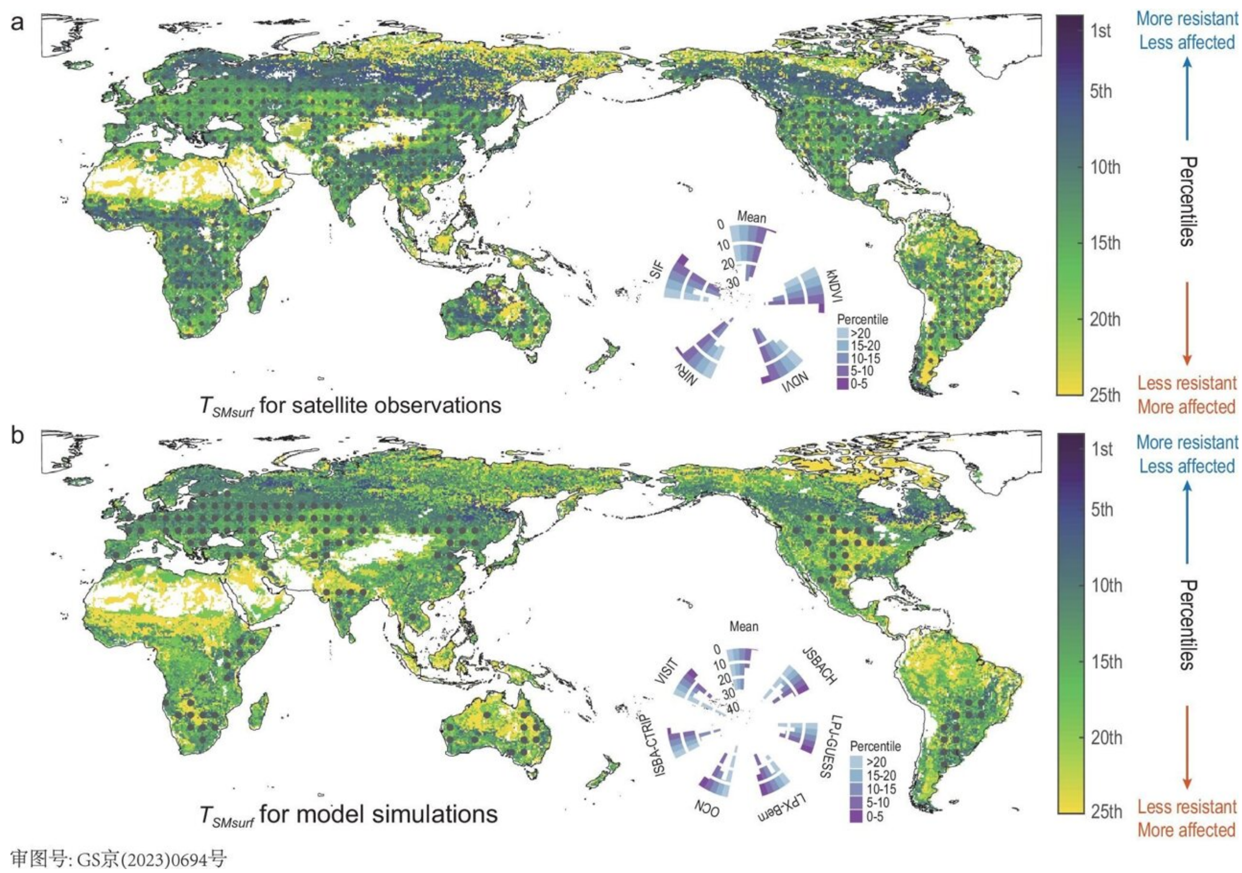

Global map of drought threshold (T_{SMsurf}) for vegetation response to surface soil-moisture anomalies during the growing season. (a) The main map of thresholds aggregated over different combinations of four satellite-based vegetation indicators and moisture content of surface soil (SMsurf) for 2001–18. Droughts are identified by anomalies of SMsurf, and changes in vegetation activity and greenness are identified by anomalies of NDVI, kNDVI, NIRv and SIF. The areas averaged by more than one single satellite data set and model simulations with maximum coincidence rates of >0.3 are marked by dots. Lower percentiles correspond to the definition of a more severe soil water deficit as drought. Under the same degree of vegetation suppression, lower percentiles for thresholds imply locations where vegetation is more resistant to drought and so affected less by arid conditions while the higher percentiles are the opposite. The inset on the right shows the distributions of satellite thresholds as small histograms for the individual combinations of SMsurf and vegetation indicators (NDVI, kNDVI, NIRv and SIF). The numbers of 0, 10, 20 and 30 in the small histograms represent the percentages of vegetated areas in different percentile subranges (b). The same format as for (a), but the spatial patterns of aggregated threshold are from model simulations during 2001–18. Droughts are identified by the same anomalies of SMsurf as in (a), but the vegetation activity is estimated by anomalies of leaf area index (LAI) from six dynamic global vegetation models (DGVMs) in the TRENDY ensembles (JABACH, LPJ-GUESS, LPX-Bern, OCN, ISBA-CTRIP and VISIT). Credit: *National Science Review* (2023). DOI: 10.1093/nsr/nwad049

In a new study, a group from Peking University, China, present a highly novel data-led method that identifies, at all locations, the onset and extent of vegetation suppression for increasing levels of drought.

The drought threshold at which damage starts to occur is identified from simultaneous data streams of both soil moisture content and satellite measurements of plant and tree "greenness." Specifically, vegetation lushness during the growing period is based on the Normalized Difference Vegetation Index (NDVI], the kernel NDVI, the near-infrared reflectance of vegetation (NIRv) and solar-induced chlorophyll fluorescence (SIF), which are the measures of vegetation greenness and productivity.

The researchers find vegetation behaves nonlinearly as soil moisture stress rises. A discovery is made of an inflection point that clearly delimits two distinct phases of the response of vegetation growth to increasing drought stress. The first phase is characterized as where vegetation is stable, and resilient to soil moisture fluctuations due to plentiful soil moisture. In the second phase, vegetation growth rapidly decreases as drought intensifies.

"Using our framework, we detect well-defined thresholds of soil moisture beyond which vegetation changes from highly resilient to highly vulnerable as soil water stress intensifies" Dr. Xiangyi Li, first author of this work, says.

The team show drought thresholds vary geographically, with more forested areas having lower thresholds, making them less sensitive to any emerging drought than less forested regions. The threshold representation, based purely on data, reveals that even state-of-the-art vegetation models often fail to describe the extent to which drought can lower vegetation health.

Conversely, current models are overly sensitive to imposed drought conditions for some humid areas with high forest cover. "Our data-driven parameter-sparse representation of drought impacts is a much-needed way to benchmark ecological models," adds Xiangyi.

Arguably the physical components of climate models have been developed over a longer period and are more reliable. Hence the researchers merge estimates of future meteorological change, including drought, with their observationally constrained descriptions of vegetation response to water stress.

This combining of lines of evidence reveals hotspots of East Asia, Europe, Amazon, southern Australia, eastern and southern Africa where the risk of drought-induced vegetation damage will increase substantially by the end of 21st Century and for a "business-as-usual" emissions scenario.

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