Temperatures are rising, but soil is getting wetter—why?

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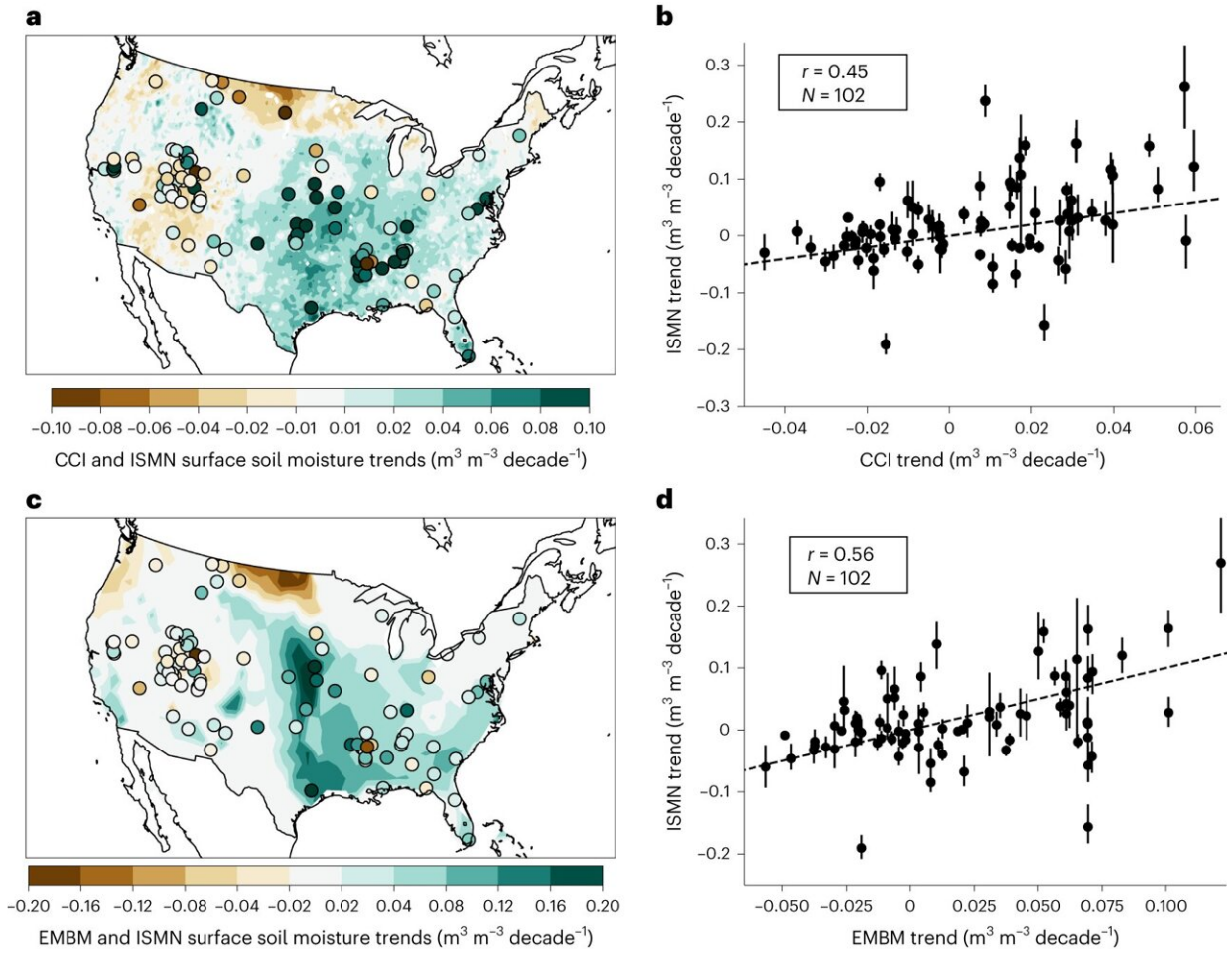

Observed and modeled soil moisture trends for the period 2011–2020. JJA surface soil moisture trends from 2011 to 2020 from observations and the EMBM. a,c, Map showing the trends from the CCI observations (a) and EMBM (c) (color shading) and the mean estimates from 1,000 bootstrap samples of the ISMN trends (circles). Note the different color bars in a and c. b,d, Trends from

the ISMN probes as a function of the co-located trends in the CCI observations (b) and EMBM (d). The dots show the mean values from the samples and the error bars show the interquartile range of the ISMN trends from 1,000 bootstrap samples at each station. The dashed black line represents the one-to-one line, or an ideal situation where observations agree perfectly with one another, and the EMBM output. The r value refers to the correlation between the mean trend across the bootstrap samples from the ISMN data and the trend in the co-located CCI and EMBM data, and N indicates the number of points in the scatter. Credit: *Nature Water* (2024). DOI: 10.1038/s44221-024-00193-x

Soil moisture can determine how quickly a wildfire spreads, how fast a hill turns into a mudslide, and perhaps most importantly, how productive our food systems are. As temperatures rise due to human-caused climate change, some researchers are concerned that soils will dry. However, between 2011 to 2020, soil moisture increased across 57% of the United States during summer, the warmest time of year.

Why did soil get wetter even as the planet got hotter?

A recent study from Harvard University researchers has found that precipitation, rather than temperature, overwhelmingly explains soil moisture trends. While it's not surprising that more rain means wetter soil, the research challenges a long-standing assumption that increases in global temperatures will lead to drier soils.

The work is published in the journal *Nature Water*.

"Atmospheric water has often been used as a proxy for drought, but this paper highlights distinctions between the hydroclimate of soils and the temperature and hydroclimate of the atmosphere," said Peter Huybers, Professor of Earth and Planetary Sciences in the Faculty of Arts and Sciences and of Environmental Science and Engineering at the Harvard

John A. Paulson School of Engineering and Applied Sciences, and senior author of the paper.

The research team found that drying from increased temperature was largely balanced by CO_2 fertilization, which allows plants to use water more efficiently. Both these effects are secondary relative to rainfall and tend to cancel each other out—leaving precipitation as the primary driver of soil moisture.

One challenge in studying soil moisture is a sparsity of data and the frequent disconnect between satellite data and ground level observations. The team compared ground level observations between 2011 and 2020—the short time period during which many soil moisture measurements are available across the United States—with satellite data and found a similar increase in soil moisture.

These findings highlight the importance of improving predictions of long-term changes in precipitation in response to climate change, especially in relation to food production.

"We don't have very accurate measurements of long-term soil moisture, but the consequences of high temperatures for agricultural yields have a lot to do with water availability," said Lucas Vargas Zeppetello, who was a Fellow at the Harvard University Center for the Environment and is first author of the study. "Plants are generally less sensitive to temperature if they have sufficient water, but in dry conditions they can get in big trouble."

Vargas Zeppetello is now an assistant professor at UC Berkeley.

"Our results suggest that reduced surface soil moisture is far from a foregone conclusion given the uncertainty in precipitation trends around the globe," said Huybers. "With uncertainties in the interannual

variability of rainfall and uncertainties in predictions of long-term rainfall, it's virtually impossible to predict soil moisture in the coming decades."

That uncertainty makes it difficult to predict growing conditions for crops, making it all the more important to focus on water management strategies, said Vargas Zeppetello.

The research was co-authored by Aleyda M. Trevino, who received her Ph.D. from Harvard in 2023 and is currently a postdoctoral fellow at San Francisco State University.

More information: Lucas R. Vargas Zeppetello et al, Disentangling contributions to past and future trends in US surface soil moisture, *Nature Water* (2024). DOI: 10.1038/s44221-024-00193-x

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