Yale SCHOOL OF THE ENVIRONMENT

Ucross High Plains Stewardship

FELLOWSHIP BRIEF

Soil greenhouse gas exchange along a temperature gradient in the North American Central Grasslands

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The Need.

Temperate grasslands cover 8% of the global land surface and provide important ecosystem services, such as soil carbon storage, atmospheric methane uptake, and forage for livestock and wildlife. Grasslands are water and nitrogen limited and characterized by low rates of carbon uptake (plant productivity) and loss (microbial decomposition). Grasslands exist across a range of climates and our understanding of how ecosystem function differs across large spatial scales remains uncertain. Previous work has suggested that in the North American Central Grasslands, colder sites have larger pools of soil carbon than those with warmer climates, probably due to lower rates of decomposition at the colder sites. However, no one has yet directly measured how soil greenhouse gas fluxes are different across climatic gradients in the Central Grasslands. A better understanding of how soil greenhouse gas fluxes differ across similar ecosystems with different historical climates can help us predict how these fluxes may change under future environmental conditions.

The Project.

This study investigated whether there are differences in soil greenhouse gas fluxes and carbon storage in semi-arid temperate grasslands, which are functionally similar except for having different temperature regimes. Uthara hypothesized that at sites with higher mean annual temperatures, there would be larger carbon dioxide emissions, nitrous oxide emissions, and methane uptake because microbial biochemical processes happen faster at higher temperatures, and that soil carbon would be lowest because rates of plant productivity are similar across sites, but decomposition will be slower at colder sites. To test this, Uthara took greenhouse gas flux measurements and soil samples at sites in Texas, New Mexico, Colorado, Wyoming and Montana, which created a latitudinal gradient along the western edge of the North American Central Grasslands. These sites have different mean annual temperatures but receive roughly the same amount of annual precipitation and have similar soil characteristics, vegetation, and land use. Using a mobile gas analyzer setup, Uthara measured soil carbon dioxide, nitrous oxide, and methane fluxes at each site during summer 2023. Uthara took soil samples down to 50cm to estimate soil texture, pH, and total carbon and nitrogen across sites.

The Findings.

Uthara found soil methane uptake varied temporally, but rates of uptake were highest at the coldest site. This went against her hypothesis that warmer sites should have higher rates of methane uptake because of the relationship between temperature and methane oxidation. Results were likely influenced by the time of year when sampling occurred. At some of the southern sites, microbial activity (and therefore methane uptake) may have been depressed due to the very high soil temperatures recorded during that sampling event.

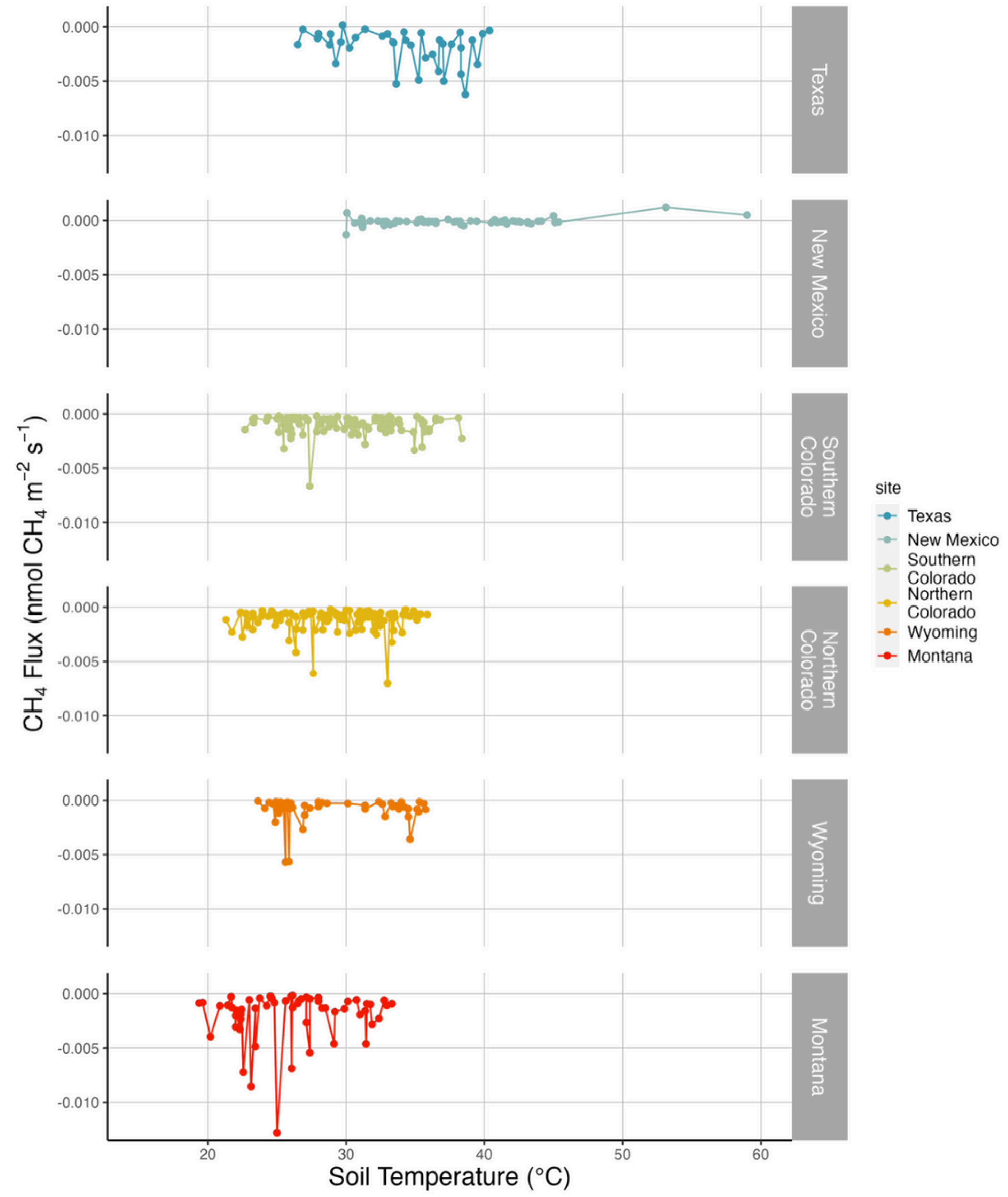

Figure: Soil methane flux by soil temperature faceted by sites. Each point represents a different sample taken across the plot and multiple days.

The Impact.

Data was collected as a part of a larger study which explores how historical temperature regimes will interact with global change factors (e.g., warming and nitrogen deposition) to influence soil greenhouse gas exchange and carbon storage in temperate grasslands. During the summer of 2023, Uthara established warming and added nitrogen treatments at each of these sites as well. Results from this past year suggest that seasonal variability plays an important role in influencing how soil greenhouse gas fluxes change across large spatial scales. Over the next three years, Uthara will return and measure greenhouse gas exchange at multiple points during the growing season across treatments and sites. At the end of the experiment, Uthara will estimate soil carbon and nitrogen pools across treatments and sites as well. Given the large pools of organic matter and limited opportunities for carbon sequestration in these systems, understanding how global change may affect greenhouse gas exchange differently in grasslands based on historical climate has important implications for better managing and predicting the earth system response to climate change. Understanding how historical conditions affect ecosystem sensitivity to global change can help environmental managers, federal agencies, and private landowners better prepare for the impacts of climate change, which are specific to the system they are managing.

The Student.

Uthara Vengrai, Western Resource Fellow | Uthara is an ecosystem ecologist and doctoral student at the Yale School of the Environment. Her research explores the role of land use and global change on soil greenhouse gas exchange and organic matter pools in dryland ecosystems. Originally from Southern California, her academic interests are strongly motivated by a desire to produce research that helps inform and prepare communities in the West for the impacts of climate change. Uthara has a BS in Environmental Sciences from the University of California, Berkeley and an MESc from the Yale School of the Environment. See what Uthara has been up to. | Blog