METER
ENVIRONMENT

THE EFFECTS OF ENVIRONMENTAL CHANGE ON CARBON CYCLING ACROSS THE SEMI-ARID WEST

Increased nitrogen availability has the potential to alter many ecosystem functions—and is doing so already. This is due to the widespread response of net primary productivity (biomass) and soil respiration to increased nitrogen inputs into the biosphere. Increases in nitrogen inputs are responsible for the acidification of soils, streams, and lakes and can affect forest and grassland productivity. Former G.A. Harris Fellowship winner, Christopher Beltz, a PhD student at Yale University, and his research team are examining two major drivers of carbon cycling: water and nitrogen. They want to understand the degree of limitation by both of these factors in the semi-arid ecosystems of the western United States and if that limitation changes by specific function.

INSPIRED BY A MITIGATION PILOT PROJECT

Beltz decided to study the effects of increased nitrogen on biomass after learning about the initiation of a major energy development in a sagebrush steppe system which caused declines in a local mule deer herd. He says, “One hypothesis was that the development significantly reduced available winter range forage and also impacted the use of it as the animals moved more quickly through the noisy environment. They wanted to see if the widespread application of fertilizers would potentially offset the loss of biomass and increase the forage quality. In the end, it was clear that the effect of nitrogen fertilization alone would have minimal to no effect. However, we also noticed some variability in the results and that this variability seemed to be related to precipitation.”

Beltz thought that if he could control the water in a system in addition to nitrogen, the results might be more consistent. Thus, Beltz and his research team broadcast nitrogen over the soil at three semi-arid grassland and shrubland/sagebrush sites in Colorado and Wyoming. He says, “The three sites essentially have a similar species list, annual precipitation, and annual temperature. However, temperature increases as you go south, and there are some differences in seasonality. The shrublands in the far north are the driest in the late summer which is typical of shrublands, where you see a large amount of precipitation occurring in the spring with a deficit in the summer. Larger taproots are beneficial in this system because they can access deeper water reservoirs."

MEASURING SOIL MOISTURE IMPROVES UNDERSTANDING

The team used METER weather stations, soil moisture sensors, and data loggers to monitor site conditions (i.e., precipitation, air temperature, soil moisture, and soil temperature) with high temporal resolution. Beltz explains, "We monitored soil moisture to understand whether our treatments were having any effect. We needed to know if the treatments actually altered the soil water conditions. With soil sensors in the ground, we could monitor that. We also monitored precipitation at the site level because of the fine-scale spatial heterogeneity of precipitation in these systems. We weren't confident we could obtain this with interpolation or modeling; we wanted site-specific values."

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Beltz uses this and other data to understand the interactive effects of nitrogen and water and also changes in water and nitrogen concentrations. He says, "We do a classic full-factorial manipulation outdoors. We perform the exact same manipulations with the same timing at each site. We measure a whole suite of variables that range from ecosystem structure to ecosystem function. This includes soil respiration, plant community, soil microbial communities (fungal and bacterial) using next-generation sequencing. We look at pools of soil carbon, and we do some fractionation so we can get at more labile and recalcitrant carbon compounds."

Beltz says that monitoring soil moisture at multiple depths is important. "Our soil samples come from the same depths as the sensors so we can differentiate depth when we look at changes in bacterial or fungal composition. We then try to tie that to temperature and moisture. In 2018, we added an additional set of soil moisture sensors in our water treatment so we could start to quantify the effect in the soil depth that those water treatments were having. This helped explain a lot of what we were seeing."

NITROGEN OR WATER: WHICH IS THE DRIVER?

Beltz says the analyses are ongoing, but what they've learned so far is that an application of water equivalent to 12 millimeters precipitation penetrates to 10 centimeters of depth, and the effect of that application lasts three to seven days at all of their sites. He says, "Last year, we had an unseasonably large amount of precipitation at our northerly site. So for most of the season, the water treatments and the controls were identical in terms of water availability. That was a very helpful context for us because we started to see things that did not match the expected patterns."

Looking at the big picture, he adds, "What's come out of this is not what anybody expected. One major finding, at least in the initial analyses at two of our sites, is that it's really the combined treatment of increased nitrogen and water that has the effect. This is not necessarily surprising in some ways, however it is the widespread lack of response of any other treatment combination that is extremely interesting."

WHAT IT ALL MEANS

Beltz sums up the implications of his research like this: "We know water availability and precipitation will shift globally due to climate change, as well as nitrogen deposition and availability. Our research is trying to tease apart the effects of two factors, at least within the western United States, that we know are likely to cause changes to the structure and function of dryland ecosystems. As we start to look at carbon balance or shifts in function or species competition of plant communities, we are finding out that it's the combined effect of increased nitrogen and water that will cause a more major change as opposed to just one or the other. It's important that we integrate that combination into models that often do not account for both of these factors."

Beltz says in the future he's interested in continuing his work in the carbon/nitrogen cycle world, and he wants to look at integrating nitrogen and water into carbon balance modeling efforts.

You can read more about the first study mentioned, regarding nitrogen fertilization in the sagebrush steppe, which was published in PloS ONE: https://doi.org/10.1371/journal.pone.0206563

Find out about his research here: christopherbeltz.com or via Twitter @BeltzEcology

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