Functioning of terrestrial ecosystems is governed by three main factors

September 22 2021

The experimental site in Torgnon (Italy), a grassland located at about 2100 m in the Western Italian Alps, and belonging to the Integrated Carbon Observation System (ICOS) and FLUXNET network. Credit: Marta Galvagno

Ecosystems on Earth's land surface support multiple functions and

services that are critical for society, like biomass production, vegetation's efficiency of using sunlight and water, water retention and climate regulation, and ultimately food security. Climate and environmental changes, as well as anthropogenic impacts, are continuously threatening the provision of these functions. To understand how terrestrial ecosystems will respond to this threat, it is crucial to know which functions are essential to obtain a good representation of the ecosystems' overall well-being and functioning. This is particularly difficult since ecosystems are rather complex in terms of their structure and their responses to environmental changes.

A large international network of researchers, led by Dr. Mirco Migliavacca at MPI BGC and iDiv in Germany, tackled this question by combining multiple data streams and methods. The scientists used environmental data from global networks of ecosystem stations, combined with satellite observations, mathematical models, and statistical and causal discovery methods. The result is strikingly simple: "We were able to identify three key indicators that allow us to summarize how ecosystems function: the maximum realized productivity, the efficiency of using water, and the efficiency of using carbon" says the study's first author Dr. Migliavacca.

The maximum productivity indicator reflects the capacity of the given ecosystem to uptake CO_2. The water use indicator is a combination of metrics representing the ecosystem water use efficiency, which is the carbon taken up per quantity of water transpired by plants. The carbon use efficiency indicator reflects the use of carbon by an ecosystem, which represents the carbon respired versus carbon taken up. The surprising findings made the team reflect on how complex ecosystems are ultimately driven by a small set of major factors just like was found, for instance, for leaf photosynthesis based on a handful of leaf traits.

"Using only these three major factors, we can explain almost 72 percent

of the variability within ecosystem functions," Migliavacca adds. "With water-use efficiency being the second major factor, our results emphasize the importance of water availability for ecosystems' performance. This will be crucial for climate change impact considerations," says last author Prof Dr. Markus Reichstein, director of the department Biogeochemical Integration at MPI BGC and iDiv.

The researchers inspected the exchange rates of carbon dioxide, water vapor, and energy at 203 monitoring stations around the world that belong to the FLUXNET network, a collaborative network of multiple research teams and field sites that collect and share their data. The selected sites cover a large variety of climate zones and vegetation types. For each site, they calculated a set of the ecosystems' functional properties, and further included calculations on average climate and soil water availability variables as well as vegetation characteristics and satellite data on vegetation biomass.

The three identified functional indicators critically depend on the structure of vegetation, that is vegetation greenness, nitrogen content of leaves, vegetation height, and biomass. This result underlines the importance of ecosystem structure, which can be shaped by disturbances and forest management in controlling ecosystem functions. At the same time, the water and carbon use efficiency also critically depend on climate and partly on aridity, which points at the critical role of climate change for future ecosystem functioning. "Our exploratory analysis serves as a crucial step towards developing indicators for ecosystem functioning and ecosystem health," summarizes Reichstein, "adding to a comprehensive assessment of the world's ecosystems response to climate and environmental changes."

More information: Migliavacca, M. et al, The three major axes of terrestrial ecosystem function. *Nature* (2021). doi.org/10.1038/s41586-021-03939-9