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# Semi-arid ecosystems emerging role in global carbon cycle dynamics

Each year, terrestrial ecosystems take up a significant fraction of anthropogenic $CO_2$ emissions, thereby slowing the increase in greenhouse gases and global warming. In 2011, global land carbon uptake was estimated to be a record breaking 40% of annual fossil fuel and land-cover change $CO_2$ emissions. Research published in this week's issue of the renowned journal Nature, demonstrates that enhanced semi-arid ecosystem productivity in Australia, South America, and South Africa explain much of this strong land sink. The emerging role of semi-arid ecosystems on inter-annual global carbon budget dynamics is unexpected and due to a combination of greater than average rainfall in 2010 and 2011 and also long-term changes in dryland vegetation.

An international research team determined that enhanced carbon uptake was related to La Niña driven rainfall increases in 2010 and 2011 that were superimposed on a 30-year dryland greening trend. These surprising interactions between vegetation-greening trends and climate extremes requires an expansion of ecological research beyond the well-studied tropical and high-latitude biomes to include the emerging role of dryland systems in the earth system.

“We first became aware of the record land-carbon sink in 2012 when compiling information for the Global Carbon Project annual carbon budget assessment”, says Ben Poulter, who led the Nature study while based at the Laboratoire des Sciences du Climat et l'Environnement (LSCE), in Saclay, France, “however, at the time, the climate and remote sensing data were unavailable to help us identify the location of the anomaly or the mechanisms responsible.”

Using a range of datasets and modeling approaches, including an atmospheric $CO_2$ measurements, factorial simulations with a dynamic global vegetation model, MODIS and AVHRR satellite derived net primary productivity and vegetation greening data, the authors identified dryland systems across the Southern Hemisphere, in particular, Australia, as having particularly high productivity in response to increased La Niña phase rainfall anomalies.

“What surprised us was that no analogous biosphere response had occurred during similar climatic extremes in the past, prompting us to explore whether previously documented dryland-greening trends were responsible for changes in carbon cycle dynamics” said Philippe Ciais, co-author and senior scientist at LSCE.

Indeed, the authors discovered that between the periods of 1982-1996 and 1997-2011, a number of ecosystem processes had become more sensitive to variations in precipitation. The enhanced precipitation sensitivity of vegetation greenness and biomass was found to lead to a fourfold increase in net-carbon uptake to precipitation over the past 30 years.

“Novel responses of the biosphere have been predicted to occur following human activities that have caused unprecedented changes in atmospheric $CO_2$ concentrations, climate, and land cover”, continues Poulter, “Our study provides new evidence that interactions among these human activities are now also impacting dryland biomes. These findings have global implications that should be considered in monitoring networks and earth system models."

The large 2011 land carbon uptake is expected to be a short-term departure in long-term global trends of rising $CO_2$ emissions, "dryland systems have high rates of carbon turnover compared to other biomes", says Ciais, "we can expect the carbon to be quickly respired or released again in wildfires, already partly reflected by the high atmospheric $CO_2$ growth rate in 2012."

"If a growing fraction of land carbon sinks, so important to slow down the progression of climate change, were to be in semi-arid regions, the overall vulnerability of land carbon will increase because those regions are more prone to disturbances (drought, fire) that lead to the return of carbon reservoirs in plants and soils back to the atmosphere", adds Josep (Pep) Canadell, co-author and scientist at the Commonwealth Scientific and Industrial Research Organisation *(*CSIRO*)* in Australia*.*

Poulter recently joined the Montana State University, where he will continue to investigate the mechanisms of dryland greening and its consequences for global carbon budgets. Cathy Whitlock, MSU Director of the Institute on Ecosystems says, "studies like these, remind us of the surprises that lie in ahead in understanding the biosphere's response to climate change. Regional perturbations in vegetation can have global consequences."

*Key Points*

- Net carbon uptake by land ecosystems ranged from 3.7 to 4.1 PgC in 2011, equivalent to about 40% of fossil fuel and land-cover change emissions, 10.4 PgC. Where 1 Pg = 1 Petagram, or $10^{15}$ gC.
- Compared to the 2000-2009 decadal average, 2011 was a larger carbon 'sink' by 1.0-1.5 PgC.
- Using an atmospheric carbon dioxide inversion, a dynamic global vegetation model, and remote sensing data, we identified semi-arid systems in the Southern Hemisphere, in particular, Australia, as contributing to 60% of the anomalous carbon uptake.
- An especially strong La Niña climate phase was responsible for increased precipitation and enhanced vegetation productivity in interior Australia and South Africa.
- The extreme precipitation event was superimposed on observations of 30-years of dryland greening, where an expansion of vegetation in Australia led to a fourfold increase in the sensitivity of carbon uptake to precipitation.
- Because carbon stocks in dryland systems have relatively high turnover compared with tropical systems, the 2011 net carbon sink is expected to release back to the atmosphere relatively fast via decomposition or fire.

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**References**

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