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CLIMATE SCIENCE

A sink down under

The finding that semi-arid ecosystems in the Southern Hemisphere may be largely responsible for changes in global concentrations of atmospheric carbon dioxide has repercussions for future levels of this greenhouse gas.

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The steady increase in atmospheric carbon dioxide, which is the main driver of global climate change, has fortunately been slowed by a simultaneous rise in CO_2 absorption by land plants, termed the land CO_2 sink[1]. However, exactly where and why this land sink is occurring has been uncertain. The main player had been thought to be tropical rainforest[2]. But in a paper published on *Nature*'s website today, Poulter *et al.*[3] draw together several lines of evidence to show that this situation may be changing, with vegetation across semi-arid ecosystems in the Southern Hemisphere taking centre stage as a driver of variations in atmospheric CO_2 levels.

Of the roughly 10 billion tonnes of carbon emitted each year from human activity, only around half remains in the atmosphere, with the rest being absorbed by the oceans and by plants on land[1]. This CO_2 sink has been growing steadily, but the situation could change as shifts in climate and human land use intensify. One warning sign of potential change is that the land sink seems to be highly sensitive to variations in temperature and rainfall over yearly timescales[4]. Advances in our understanding of the mechanisms behind this short-term variation in CO_2, such as those reported by Poulter and colleagues, provide valuable clues about the probable longer-term trend in atmospheric CO_2 over the coming century.

Unsurprisingly, given the inherent complexity of the atmosphere–land–ocean system, isolating exactly which components of the global carbon cycle are affected by yearly climate variation has proved difficult. However, large-scale assessments of carbon budgets have indicated that the culprit is somewhere on land[5], and simulations went one step further by pinpointing tropical forests as the prime suspect[2,4,6]. So far, so simple — until 2011, when scientists estimated an extraordinarily high value for the land sink which seemed to be linked not to tropical forest, but to semi-arid ecosystems in the Southern Hemisphere[7].

Enter Poulter and co-workers, who provide the most detailed account so far of the spatial patterns, and underlying mechanisms, of the record-high land sink of 2011, and more generally, of yearly variation in the land sink over the past few decades. Their results challenge the current consensus about what regulates atmospheric CO_2 from year to year, and will prove invaluable as societies struggle to predict, and adapt to, changes in a world in which both atmospheric and ecological systems are moving into unfamiliar territory.

Specifically, the authors find remarkable agreement in the magnitude of the 2011 land sink estimated from three contrasting approaches: a detailed ecosystem model simulating land–atmosphere interactions; an 'atmospheric inversion', which uses a gas-transport model to convert measurements of atmospheric CO_2 concentrations to estimates of surface CO_2 emissions; and a large-scale carbon budget, estimating land CO_2 absorption as the difference between human CO_2 emissions and the sum of the observed atmospheric CO_2 build-up and the relatively well-constrained oceanic CO_2 sink. Both the model and the inversion suggest that semi-arid ecosystems in the Southern Hemisphere (Fig. 1) are becoming increasingly valuable land CO_2 sinks — a conclusion supported by satellite data, which yield a visual record of plant growth and photosynthesis over the past 30 years.

A switch in the type of ecosystem that controls atmospheric CO_2 has major implications for the overall rate and pattern of climate change. First, different vegetation types may have different responses and sensitivities to disturbance. For example, Poulter *et al.* show that increased growth of vegetation in semi-arid ecosystems is linked not only to generally increasing levels of rainfall across these regions, but also to increasing sensitivity of the vegetation to rainfall. Worryingly, the authors also show that these links between rainfall and the land CO_2 sink in semi-arid ecosystems are currently missing from many major climate models.

Second, different types of ecosystem lock away absorbed CO_2 for different lengths of time. Rainforests store much of their carbon in dense hardwoods, which may take many centuries to die and rot[8,9], whereas much of the CO_2 absorbed across semi-arid regions is converted into relatively short-lived grasses and shrubs[10,11]. Increased effects of these more volatile ecosystems on global climate could lead to greater variability in global atmospheric CO_2 levels in the future, something that recent observations seem to confirm.

Although Poulter and colleagues use the best available models to support their conclusions, models are only as good as the data with which they are calibrated, and little information exists about vegetation in semi-arid ecosystems compared with other regions. Similarly, the pathways for CO_2 once it has been absorbed into semi-arid vegetation remain poorly

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Figure 1 | Dry drivers. Poulter *et al.*[3] report that semi-arid ecosystems in the Southern Hemisphere, such as in central Australia (pictured), drive yearly changes in global concentrations of atmospheric carbon dioxide.

understood[10,11], so there are few solid data from which to assess the stability of the CO_2 sink in such ecosystems. More broadly, semi-arid systems are vulnerable to a range of factors that are difficult to model, such as overgrazing, fire, flooding and chronic soil erosion[10,11], many of which are linked to human activity. These processes must somehow be accounted for, both in models and in policies for land use and conservation, if the invaluable function of semi-arid ecosystems as a global CO_2 sink is to be managed and maintained.

Nevertheless, Poulter *et al*. make a key contribution in highlighting the crucial, and hitherto often overlooked, role of such ecosystems in the global carbon cycle, and in identifying several important processes, which should markedly improve our understanding of future atmospheric CO_2 levels. Let us hope that their research stimulates more work on the ground to better understand and manage these fragile but essential ecosystems. ■

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