nature

COMMENTARY

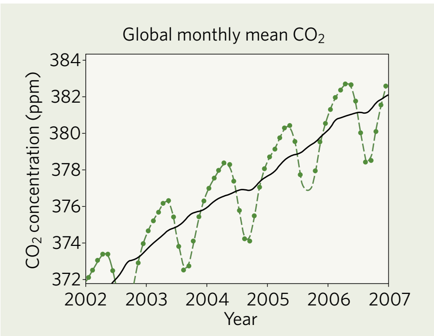
Springtime for sinks

Carbon sinks play a key role in slowing the growth of carbon-dioxide levels in the atmosphere. These sinks are at risk as the world warms, but their demise is not inevitable, say Dave Reay and his colleagues.

Across the Northern Hemisphere spring is creeping northwards. On the trees the buds are bursting, their leaves unfolding to luxuriate in an atmosphere more enriched in carbon dioxide than at any time in the previous 650,000 years. In the next few months, global CO_2 concentrations will start declining from their annual — and record-breaking — peak (see graphic[1]). This happens as the northern biosphere converts more and more atmospheric CO_2 into carbon for storage in terrestrial sinks, such as plants and soils.

With longer growing seasons and earlier spring 'greening', the amount of carbon accumulating in the terrestrial biosphere increased from 0.2 ± 0.7 billion tonnes per annum in the 1980s to 1.2 ± 0.7 **[Q.1]** billion tonnes in the 1990s. But if the terrestrial carbon sink has played a part in slowing the rate of recent CO_2 increase, the oceanic carbon sink — which mops up twice as much atmospheric carbon as the land sink — has been even more crucial. Together, these sinks sequester around half of the 6.4 billion tonnes of anthropogenic carbon emitted each year. As such, they are key to determining how rapidly atmospheric CO_2 concentrations, and so global temperatures, will increase during the twenty-first century.

What does the future hold for these sinks? The latest evidence, summarized by the Intergovernmental Panel on Climate Change (IPCC) Working Group II report (WGII) last week, suggests that we cannot rely on the terrestrial and oceanic sinks to go on mopping up our excessive CO_2 emissions indefinitely. Of course, the uncertainties surrounding the impacts of climate change on these carbon sinks are large, but in our view that is no excuse for inaction. By exploring ways in which we can enhance carbon sequestration, we can make the land (and perhaps even the ocean) sinks part of the solution to human-induced climate change, rather than part of the problem.



As reported by the IPCC, global warming tends to reduce both land and ocean uptake of atmospheric CO_2, so increasing the fraction of anthropogenic emissions that stays in the atmosphere. If we take the globally averaged CO_2 concentrations since 1980 and add to these the additional CO_2 that might have accumulated in the atmosphere without the terrestrial and oceanic carbon sinks, we estimate 10% higher CO_2 concentrations in 2006.

Sink to source

Given its importance, it is surprising that the impacts of climate change on the huge oceanic carbon sink received scant coverage in the latest WGII report. Uncertainty is doubtless to blame, even though some effects are well understood. As long as CO_2 is increasing in the atmosphere, the ocean will continue to take up carbon. But as CO_2 concentrations rise, oceanic pH will fall, and with the changing chemistry of the ocean the efficiency with which it absorbs carbon is projected to decrease.

There are other indirect ways that climate change could affect the future oceanic sink. Some changes, such as rising seawater temperatures and increased stratification — whereby less mixing between layers may starve surface waters of nutrients — may reduce CO_2 uptake. Others, such as increased CO_2 uptake in the high-latitude ocean due to less sea-ice cover and increased biological productivity, could increase oceanic uptake. Still, most climate models predict that a smaller fraction of anthropogenic CO_2 emissions will be absorbed over time as the ocean acidifies[2].

Worse may be in store for the land sink. According to the WGII report, terrestrial ecosystems are highly likely (more than a 90% chance) to become net sources of CO_2 in the latter half of the twenty-first century. This is the strongest statement yet on terrestrial carbon, and one with huge implications for global climate change. According to the IPCC's latest predictions, the decline in the oceanic sink and a switch from carbon sink to source on land would increase the global temperature in 2100 by more than 1 °C.

The future of the terrestrial carbon sink may appear bleak, but it doesn't have to be. Yes, the elevated global temperatures and changes in precipitation predicted for 2050 could induce a switch from sink to source as warmer soils release more carbon and forests suffer more drought. In reality, things are more uncertain. Humans have been managing terrestrial ecosystems to our own ends for millennia — from deforestation and agriculture, to increasing fertilizer and pesticide use. Of the 50 billion tonnes **[chk]** of carbon currently locked up in terrestrial biomass and vulnerable to release in the next 20 years, 40 billion **[chk]** is put at risk not by changes in climate, but by changes in land use. Climate change may be the greatest threat to this huge carbon stock towards the end of the century. In the shorter-term, it is chainsaws and ploughs, not drought and extreme temperatures, that we must address.

Hope for the future

Some may see our transformation of Earth's land surface as part of the problem, that the combined grip of more than 6 billion people is squeezing the terrestrial carbon sinks from every direction. But in this powerful grip may also lie part of the solution.

Deforestation is the single biggest threat to the terrestrial carbon sink. Over the past 200 years it is thought to have been responsible for 30% of the anthropogenic increase in atmospheric CO_2 concentrations[3]. Slowing deforestation rates could therefore help to stabilize carbon emissions from terrestrial ecosystems[4], as could enhanced carbon uptake through afforestation and reforestation.

The conversion of soils from natural to agricultural use has also led to substantial losses in terrestrial carbon. Throughout history, soils are thought to have lost between 40 and 90 billion tonnes **[chk]** of carbon globally through cultivation and disturbance[5]. Again, sensitive land-use practice can help to protect the remaining soil carbon stocks, and perhaps reverse recent trends. Through practices such as no-till agriculture, more efficient fertilizer use, and the planting of vegetation with higher carbon returns to the soil, the soil sink can be significantly enhanced[4]. A 2001 IPCC report concluded that through such approaches a cumulative increase in terrestrial carbon of up to 100 billion tonnes is possible by 2050.

Carbon sinks are at greater immediate risk from land-use changes than from global warming.

Despite their huge potential, protecting or enhancing carbon sinks has received inadequate attention from the international community. In 2001, the Kyoto Protocol members agreed that richer nations could use their carbon sinks to meet their Kyoto commitments to reduce emissions. As part of the Protocol's Clean Development Mechanism (CDM), rich nations were also able to count cuts in emissions achieved through afforestation and reforestation projects in developing countries. But sinks could only be used to meet a small part of their total commitment and, of the more than 570 registered CDM projects at the time of writing, only one — the reforestation of degraded land in China's Pearl River Basin — is actually aimed at sink enhancement.

> **"Protecting or enhancing carbon sinks has received inadequate attention."**

The 2008–2012 commitment period for the Kyoto Protocol is coming to an end and the question of what will follow is the subject of much debate. Terrestrial sinks are time limited and reversible, so do not replace the need for emissions reduction. But to make them part of the wider solution they must be better integrated into future international agreements.

A quick fix?

In general, any approach to mitigating emissions or adapting to climate change needs to consider the potential feedbacks on both terrestrial and oceanic carbon sinks. For example, biofuels are growing in popularity as a direct substitute for fossil fuels because of the hope that they can partly offset carbon emissions. A recent estimate suggests that, by 2030, about 750 million tonnes of fossil carbon emissions could be offset by biofuels each year[6]. But some biofuels, such as corn ethanol, have similar net carbon emissions to fossil fuels[7]. It is also likely that any massive increase in biofuel production would be at the expense of existing vegetation and soil carbon sinks.

Can we do anything to enhance the much larger oceanic carbon sink? Efforts to enhance ocean productivity, and therefore carbon uptake, through iron or urea fertilization have had short-term results in areas such as the Southern Ocean. But visually impressive algal blooms may do little to enhance long-term carbon uptake. To make any difference on a global scale you would need to keep fertilizing, indefinitely, a much larger area of the ocean. Attractive as the idea of a 'quick fix' for human-induced climate change may be, such schemes are expensive and their side effects poorly understood. Perhaps climate change will be so rapid, its impacts so severe, that such geoengineering will one day be required. Today though, it is through the protection and enhancement of the terrestrial carbon sink that we can better engineer our future climate. ■

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