Catching carbon

Meeting climate targets will require considerable carbon dioxide removal in addition to emission cuts. To achieve this sustainably, a range of methods are needed to avoid adverse effects and match co-benefits with local needs.

In 2015, governments from around the world signed up to the Paris Agreement, with the aim of limiting global warming to well below 2 °C, and preferably below 1.5 °C. Since then, greenhouse gas emissions have continued to rise. However, new national pledges made at last year's COP26 meeting could still keep us below 2 °C (ref. [1]). While this provides room for optimism, turning these pledges into reality remains a challenge, and pledges will need to go even further to get close to 1.5 °C. Reducing emissions will not be enough. Mitigation pathways consistent with these targets will require the use of carbon dioxide removal strategies[2], but these will need to work sustainably alongside other essential activities such as agriculture and biodiversity conservation.

Carbon dioxide removal cannot replace vital emission cuts, but can help to offset emissions that are harder to eliminate entirely, and crucially enable countries to achieve net-zero sooner. The extraction of carbon dioxide from the atmosphere can be achieved through enhancing biological, geochemical, or chemical sinks[1]. There is no shortage of ideas on how to do this. However, at large scales, many approaches place considerable demands on natural resources.

Successful implementation of any carbon dioxide removal approach will require careful consideration of other land-use needs. Reforestation and improved forest management are well-established approaches which can store carbon as well as enhance biodiversity[3], but the benefits are constrained by land availability. Around half of the world's habitable area is currently devoted to agriculture required to feed growing populations[4]. One way to expand capacity is through agroforestry, whereby trees are incorporated into agriculture such that the land can support food production, carbon uptake, and increased biodiversity. However, this requires expert management and can lead to trade-offs with crop production.

Expansion of tree cover can contribute to carbon dioxide removal, but we cannot solely rely on this given the space constraints. Another promising option is to speed up the natural weathering of silicate rocks, a process which removes carbon dioxide from the atmosphere. This could be achieved by spreading crushed silicate rocks over agricultural land, avoiding additional space requirements. In an Article in this month's issue, Beerling and colleagues suggest that implementing this strategy in the UK could deliver up to 45% of the carbon dioxide removal required for the country to achieve net-zero by 2050. In addition, they show that enhanced rock weathering could also benefit agriculture by reversing soil acidification and reducing the need for fertilizer. Co-benefits such as these could help to incentivize deployment, and ensure long-term adoption.

A wide array of other possible carbon removal methods exist, from restoration of wetlands[3] to direct extraction of carbon dioxide from air by facilitating chemical bonding[5]. Each approach offers different benefits, as well as its own challenges. While many strategies have been shown to be technically feasible, few have been demonstrated in practice or widely adopted. Efforts to speed up development of immature technologies will be needed to maximize the options at our disposal.

Careful consideration must also be given to possible unintended consequences. For example, changes in forest cover can directly impact rainfall[6] and surface temperature by modifying surface fluxes. Also in this issue, in an Article Van Dijke and colleagues show that implementing large-scale tree restoration could cause significant shifts in regional water availability globally. These direct influences on local and downstream climate could be beneficial or detrimental depending on location. Ocean-based strategies, such as ocean fertilization, could have complex and difficult to predict impacts on marine ecosystems[2]. Comprehensive monitoring of carbon removal technologies will be needed to measure their long-term effectiveness, as well as any environmental impacts.

Carbon dioxide removal is likely to become increasingly important in the coming years in combating climate change. Successful implementation will rely on having a wide range of sufficiently developed options available. This will enable deployment of the right methods and technologies in the right locations to maximize co-benefits and minimize adverse environmental impacts. ❐

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