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Land carbon sinks – Met Office short briefing

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Land-based carbon sinks, such as soils and forests, have strengthened over the past six decades, meaning they have taken up increasing amounts of carbon in proportion to increasing anthropogenic CO_2 emissions. The interannual and decadal variability in the strength of their carbon uptake indicates that these sinks are sensitive to climate conditions and therefore to climate change[1]. Well established Earth System Model simulations of future climate show an overall weakening in future carbon sinks in response to climate change. This short briefing seeks to present the latest scientific results and opinions around several recent questions raised in this area.

To what extent is there a scientific consensus on the strength of the land carbon sink?
There is scientific consensus on the long-term response of the global land carbon sink to rising greenhouse gas emissions. The IPCC Sixth Assessment Report concluded that both land and ocean carbon sinks will take up progressively more CO_2 in total each year as emissions rise. However, as cumulative emissions increase faster than sinks can absorb carbon from the atmosphere, the proportion of anthropogenic emissions absorbed will decrease. This results in a higher proportion of emitted CO_2 remaining in the atmosphere[1]. At shorter timescales, and on the scale of individual carbon sinks, such as the Amazon, more research is needed to understand responses to short-lived extreme events such as wildfire, and anthropogenic pressures such as land use change. Some carbon sinks can become sources under certain conditions. Continued long-term land carbon sequestration is possible through the end of this century under multiple emissions scenarios, especially with nature-based climate solutions and appropriate ecosystem management[2].

Is the land carbon sink weakening as a result of climate variability and change?
Recent research has shown that a climate change-induced increase in wildfire acts to weaken regional land carbon sinks, such as in Amazonia in 2023[3]. While fire and prolonged drought are known to weaken regional land carbon sinks, even accounting for this changed behaviour, globally the land carbon sink was still a net absorber of carbon in 2023, but at a significantly reduced rate compared to previous years[4]. This weakening in the land carbon sink also reduces remaining carbon budgets by 4–6%[3].

In extreme wildfire years, South America and temperate North America can shift from carbon sinks to carbon sources[3]. Conversely, dryland areas may see an increase in their capacity to store carbon owing to less wildfire in these habitats[5]. Recent research on forest carbon sinks demonstrated that they have strengthened in temperate and tropical regrowth forests but weakened in boreal and tropical intact forests[4]. Other research also found regional differences, with areas including Amazonia, Canada and Southeast Asia becoming carbon sources due to drought, wildfire emissions, extreme heat, or tree mortality[6,7]. Forest clearing for timber and pest outbreaks can also weaken regional carbon sinks[4]. El Niño is known to have regional influence on wildfire and drought risk, which affects the behaviour of land carbon sinks, however, the influence of the 2023 El Niño on the land sink on a global scale is still unclear[6].

Are the effects of extreme events on the land carbon sink included in climate model projections?
There are many types of models used to understand the current and future behaviour of land carbon sinks in a warming climate. Taken together, these models have been found to reliably represent the land carbon sinks over the long term. However, these models are less able represent the behaviour of regional land carbon sinks in response to the impact of short-lived extremes on vegetation mortality. Fire impacts, in particular, are often hard to simulate in models because of the impact of human activity, which also hinders simulation of ecosystem management impacts[6,8,9]. This contributes to considerable uncertainty in projections of future carbon sink strength[10].

Longer-duration extremes which affect larger areas, like droughts and heatwaves, are well represented in climate model projections. Some models include the impact of human activity and drought on forest extent, a key part of determining land carbon sink strength. The next version of the Met Office's UKESM model, currently in development, will also include fire impacts on biomes. 2023 was an extreme year for land carbon sinks, and work is underway to understand where model improvements can be made.

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