mechanism by which global warming may impact the occurrence of extreme eastern Pacific rainfall events during these rare El Niño episodes. Although there is considerable uncertainty regarding how the sea surface temperature variability may change, the authors find a more robust link with extreme rainfall, which is tied to the pattern of equatorial Pacific sea surface warming.

As the ocean surface warms under increasing greenhouse gas concentrations, climate models project a pattern of enhanced warming in the equatorial eastern Pacific relative to the rest of the tropical oceans[2,4]. This pattern of enhanced warming essentially reduces the barrier to deep atmospheric convection in the normally dry eastern Pacific, making it easier for a sea surface temperature increase associated with El Niño to induce extreme rainfall in the region. Thus, under global warming, Cai and colleagues find that the same El Niño-related sea surface temperature anomalies induce larger eastern Pacific rainfall events, which signifies more frequent eastern Pacific extreme rainfall even if the sea surface temperature variability does not change. Therefore, a robust change emerges when the authors define extreme El Niño by rainfall rather than sea surface temperature, which is likely to be a more useful definition for making links to remote societal impacts.

This increase in the frequency of extreme El Niño events is dependent on a pattern of enhanced warming in the equatorial eastern Pacific Ocean. How much confidence can we place in the consistency of such a pattern under global warming? Climate scientists have debated the expected tropical response to global warming, with an ocean dynamical 'thermostat' mechanism favouring suppressed eastern Pacific warming[5], but a reduction in heat transport away from the equator[2] and the expected surface latent heat flux adjustment[4] favouring enhanced equatorial Pacific warming. Contrary to the expected pattern from climate models, over the past 35–40 years the tropical sea surface temperature trend has actually featured suppressed warming in the equatorial eastern Pacific[6]. However, there is strong observational evidence of the expected enhanced equatorial eastern Pacific warming if the analysis is extended to include the past 60 years[7]. Cai and colleagues have theoretical, observational and modelling support at the foundation of their findings, nevertheless, the pattern of equatorial sea surface warming will remain an active area of research.

Another key question relates to implications for the associated changes in extreme weather under global warming, given that the severe impacts from extreme El Niño episodes depend on the interaction between the eastern Pacific rainfall and the background state. Will more frequent extreme rainfall episodes in the equatorial eastern Pacific lead to more frequent extreme impacts under global warming, or will changes in the background state alter the impacts, possibly even taming some of the effects? A recent study[8] supports the contention of the new findings, demonstrating that El Niño-related hydroclimate variability will become intensified under global warming, particularly in regions, such as southern Asia, that are already severely stressed by variations in droughts, floods and crop yields. However, the same study also notes that the changes in rainfall patterns are more complex in other regions, which invites further scrutiny when we limit consideration to extreme El Niño episodes. Potential changes in regional temperature variability raise additional questions: another recent study[9] indicates a projected decrease in temperature variability under global warming. Will extreme El Niño episodes under global warming feature muted temperature variability, or will the more frequent extreme episodes lead to more frequent extreme temperature swings in some regions?

Although some questions remain unanswered, Cai and colleagues provide a solid foundation for future investigations. Their study underscores that the frequency of extreme rainfall episodes in the equatorial eastern Pacific Ocean associated with El Niño episodes will increase as long as the region warms faster than the rest of the tropical oceans. Furthermore, the increased frequency of these extreme rainfall episodes are likely to inflict more frequent severe impacts over some regions of the world. ❐

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REDD+ POLICY

Corridors of carbon and biodiversity

Reducing tropical deforestation has huge potential for mitigating climate change and saving the Earth's most biologically diverse biome. Corridors connecting existing protected areas represent an elegant means of attaining both goals.

Oscar Venter

In Poland last year, climate negotiators finally agreed to a mechanism for paying developing countries for reducing their forest-based emissions — which account for roughly 15% of global emissions. With pitch-perfect timing, Jantz and colleagues[1] propose, in this issue of *Nature Climate Change*, a framework for harnessing these funds to contribute to biodiversity conservation in the tropics. In their paper they demonstrate that by carefully targeting carbon funds at corridors linking existing protected areas, large benefits can be gained for biodiversity conservation without compromising the new mechanism's primary aim of slowing anthropogenic climate change.

The carbon mechanism is termed REDD+ (Reducing Emissions from Deforestation and

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Figure 1 | Forested corridor in Mato Grosso, Brazil. Corridors typically store more vegetative carbon than the matrix they traverse, and potentially even more than the protected areas they connect. They can also provide viable habitat for many species, promote meta-population dynamics and make it easier for species to shift their range in response to climate change. This makes them an excellent contender for promoting multiple benefits under the new carbon payment mechanism REDD+.

Forest Degradation, plus the conservation, sustainable management and enhancement of forest carbon stocks), and it is expected to generate unprecedented funding for conservation in the tropics. As tropical forests are home to roughly half of the world's species[2], REDD+ has also been heralded as a potential boon for biodiversity conservation[3]. But carbon and biodiversity 'hotspots' don't always overlap, and the general consensus of recent studies is that tapping into potential biodiversity benefits will require the development of biodiversity-friendly methods for implementing REDD+[4].

Diverting carbon funds to projects or locations that are good for biodiversity can have drawbacks. It can either directly increase the financial costs of carbon projects or simply overburden them with additional obligations[5]. To focus on corridors, as suggested by Jantz and colleagues, seems a promising solution. Corridors often yield benefits to biodiversity disproportionate to their size, by increasing population connectivity[6] and providing safe routes for species to move with a changing climate[7], and could therefore offer a uniquely efficient way of increasing the biodiversity benefits of REDD+.

What Jantz and colleagues are suggesting in their paper is elegantly simple: invest in corridors between protected areas that traverse locations (1) high in vegetation carbon stock, (2) rich in species and (3) with low value for other economic opportunities, thereby minimizing conflict with competing land uses. Using a recent high-resolution map of vegetation carbon density[8], they go on to demonstrate how this framework can be implemented by creating a pan-tropical map of corridors, and also a more detailed map for the Amazon.

What they find is encouraging. Most importantly, investing in corridors can contribute to maintaining vegetation carbon stores. In Africa, for instance, they find that the corridors they identified stored 130 tonnes of carbon per hectare, which is substantially more than the protected areas they link. On the other hand, the authors do caution that corridors are not necessarily the most efficient path to capturing carbon. They find that by ignoring their corridor framework and instead investing in the most carbon-dense parts of the tropics, it is possible to protect the same amount of carbon in less area.

But reducing carbon emissions is about more than just protecting high carbon stores. To actually reduce emissions, those stores must be at risk of being lost through land-cover change. Because corridors typically traverse more fragmented landscapes, the authors find that carbon captured within them tends to be at greater risk of being lost than areas identified in the non-corridor approach. So although corridors may not be the most carbon-dense real estate, they are at risk of conversion and are therefore good places for reducing future land-based emissions.

Jantz and colleagues are the first to suggest using corridors for implementing REDD+, and thus open up a new area for future studies. For instance, one of the primary benefits of corridors is to assist climate-induced shifts in species ranges. To maximize this benefit, one might consider expanding the framework developed by Jantz *et al.* to identify corridors that not only pass through biodiversity-rich habitats, but also traverse important environmental gradients, such as rainfall or elevation. Moreover, much of a corridor's value lies in the protected areas it connects, so identifying corridors connecting two or more protected areas that are rich in species could also be beneficial.

The largest question left unanswered may be exactly how REDD+ corridors should be managed. Over the past decade, conservation has shifted towards greater alignment of conservation outcomes with enhancing human well-being. This is often best pursued by emphasizing local stakeholders and decision makers[9]. Unlike protected areas, which must typically be managed following a defined structure, the door is wide open for how corridors can best be managed to promote multiple benefit and long-term viability. An obvious contender for managing corridors could be through certified reduced impact logging, which allows revenues to be generated while natural values are largely maintained[10], or treating them as forest commons that serve to supply timber and non-timber forest products to local resource users[11].

Given that it has taken eight long years for agreement to be reached on the REDD+ mechanism, exactly how a corridor approach is implemented will probably be debated for some time. Still, Jantz and colleagues[1] have shown us that such an approach would have benefits for the climate, and for biodiversity. ❐

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