receipt of other recommended services (such as cancer screening) and therefore it was not associated with special attention from health services.

However, the study lacked a direct assessment of the extent of programme participation, such as the number of sessions that were attended, which has previously been shown to be the strongest tangible predictor of changes to HbA1c and weight[1]. This reflects the systemic gap in health-system data sets for reporting outcomes related to an individual's behaviour, participation and quality of life. Filling this gap will be key to improving studies of real-world strategies that seek to prevent disease.

The most unsatisfying aspect of the study was the counter-intuitive increase in diabetes diagnoses in people who were referred to the NHS DPP compared with those who were not. The authors attribute this to the difficulty in identifying diabetes diagnoses on the basis of data recorded by health services during routine care. However, because methods of identifying diabetes diagnoses from electronic health records are well-developed[12], other explanations seem more probable – such as higher baseline levels of weight and HbA1c in referred participants that meant progression to diabetes was more likely than in people who weren't referred to the NHS DPP.

Type 2 diabetes stands out among contemporary global health problems for the potential – yet missed opportunities – to reduce its incidence. Cohort studies have identified dozens of modifiable risk factors, ranging from diet and physical activity to sleep and air quality, and environmental toxins[13]. New drugs that treat obesity are also primed to reduce the risk of diabetes[14], and supplementation with vitamin D might even reduce risk of developing the condition in people with prediabetes[15].

Unfortunately, there are few organized efforts to address modifiable risk factors, and there is often a lack of clear policies that can be implemented to reduce diabetes risk. Policy-level approaches have so far focused on taxing unhealthy foods and subsidizing healthy options, communications and marketing that aim to influence behaviour, and education and urban planning to enable physical activity.

When population-wide interventions are implemented, they are difficult to study with conventional experimental approaches because of the practical and ethical challenges associated with randomization. At the same time, there has been a rapid proliferation of large-scale digitized health data and non-health data, including information about geographical location, marketing information and data from social media or wearable devices such as smartwatches. Together these factors are spurring an increase in 'natural' experimental studies of pre-existing groups and a demand for rigorous quasi-experimental designs to measure intervention effectiveness in contexts in which randomization is not feasible[16].

Lemp and colleagues' careful and rigorous methods are a valuable addition to diabetes prevention research. Although this study will not end the debate on how to implement diabetes prevention strategies across whole populations, it provides a precedent for stronger evaluation of the programmes that are already under way, and facilitates evidence-based approaches that cater to different parts of the population.

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Climate change

Emissions scenarios and targets aligned

Chris D. Jones & Alexander J. Askew

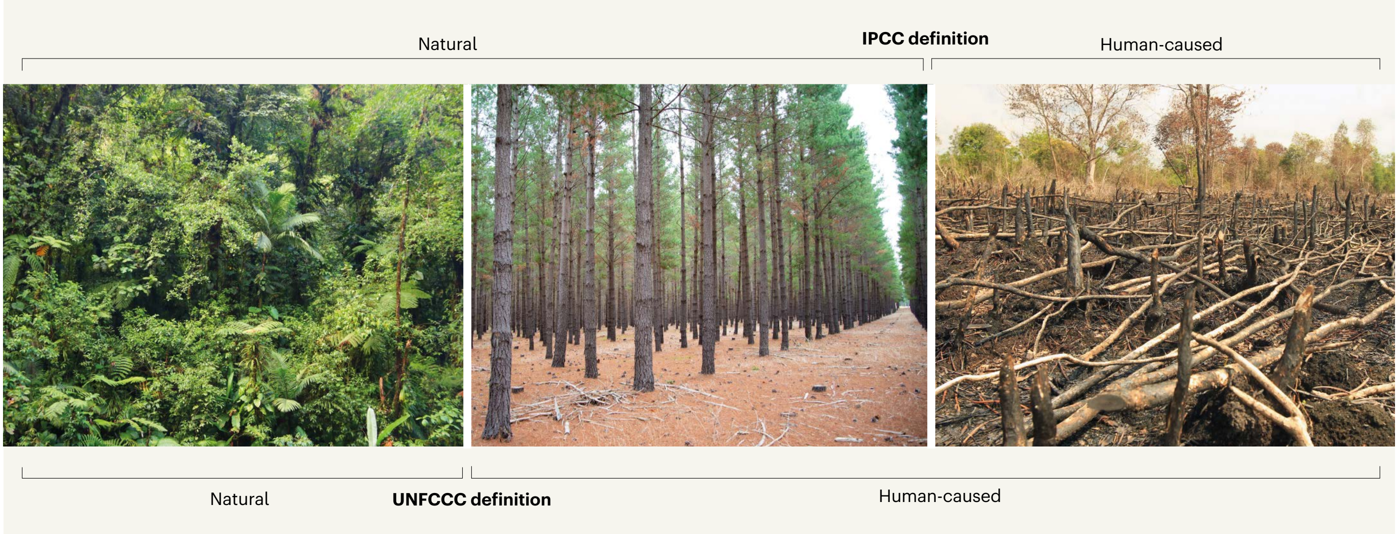
A mismatch in how carbon emissions are reported could endanger nations' best efforts to meet targets for curbing climate change. A method for translating between reporting conventions offers a path forward. **See p.102**

To halt anthropogenic climate change, the world must strive for 'net zero' emissions. The goal of net zero sounds simple – if humans stop causing carbon dioxide emissions, the world stops getting hotter. But a subtlety in the way that anthropogenic emissions are defined has increased the risk that this goal might not be met. On page 102, Gidden *et al.*[1] suggest a way of translating between existing definitions to address the issue.

It has been known for some time[2] that there is a mismatch in the ways in which different organizations define carbon emissions. The issue stems from land-use classifications, and how land use changes through activities such as deforestation. The Intergovernmental Panel on Climate Change (IPCC) defines anthropogenic on the basis of actions and processes: which processes are caused by humans, and therefore anthropogenic, and which are natural? For example, the response of forests to a changing climate would be considered natural, whereas cutting down trees would not.

By contrast, the United Nations Framework Convention on Climate Change (UNFCCC) requires that its members provide a national greenhouse-gas inventory (NGHGI) every year, using a definition that is based on geography: is a given carbon sink or source located on 'managed' land (in which case it is classed as anthropogenic) or 'natural' land? Managed land broadly refers to any land that has been subject to human intervention – including, for example, both croplands and conservation areas. If a natural process occurs on managed land, it can therefore be reported differently according to these two definitions, leading to confusion and missed targets (Fig. 1).

To explain how this plays out, it's helpful to understand the origin of the term net zero. Back in 2009, several independent studies[3–8] showed that the expected increase in global temperature this century depends on the total amount of CO_2 emitted. Any climate goal should therefore include a cap on CO_2 emissions, known as a carbon budget. 'Budget' implies that some accounting is required to measure total emissions: collective global actions that generate emissions can be balanced by activities that remove carbon from the atmosphere, resulting



L TO R: TUPUNGATO/SHUTTERSTOCK; ADWO/SHUTTERSTOCK; HASIHOLAN SIAHAAN/SHUTTERSTOCK

Figure 1 | Defining 'anthropogenic' through land-use classifications. The Intergovernmental Panel on Climate Change (IPCC) defines the term as applying to processes that are caused by humans, as opposed to natural ones, whereas the United Nations Framework Convention on Climate Change (UNFCCC) defines it in the context of processes occurring on 'managed' land (involving some form of human intervention) as opposed to 'natural' land. Natural processes occurring on natural land (left) and processes caused by humans on managed land (right) are reported identically to both organizations, but this is not the case for carbon sinks on managed land (centre). The IPCC's definition sets the benchmark for reaching 'net zero' emissions to halt global warming[11], whereas the UNFCCC compiles reports of national emissions that could reach net zero ahead of the IPCC's estimates – a mismatch that could lead to missed targets. Gidden *et al.*[1] provide a translation method to fix the problem.

in net-zero emissions.

Crucially, the idea that net zero would halt global warming relies on the fact that natural carbon sinks will continue to remove CO_2 from the atmosphere, reducing the greenhouse effect and offsetting any ongoing global warming. The removal of this CO_2 is classed as a natural process and is therefore not included in what are counted as emissions from human activity.

Emissions from activities involving land-use change have always been large – until around 1950, they even exceeded those from fossil fuels[9]. Some of these activities (such as reforestation) remove carbon and can be classed as giving rise to 'negative emissions'. These are expected to grow considerably in this decade and beyond[1], and one might assume that they can be included in the global total on the path towards net zero. But this is where the two different ways of defining anthropogenic begin to complicate matters.

The NGHGI definition includes natural carbon-sink processes on managed land, so the emissions reported to the UNFCCC are effectively undercounted. This means that the UNFCCC will declare global net-zero emissions to have been achieved several years earlier than would be the case according to the IPCC definition. This mismatch is mentioned in a report[10] issued earlier this year by the IPCC, but it is included only as a footnote, and the report does not quantify what is required to restore consistency.

An obvious way to fix this problem might be to amend the definitions. Sadly, this approach is unlikely to be adopted because the terminology is well established, and both definitions have evolved this way for a reason; neither is right or wrong – they just differ. The IPCC assesses the science of climate change, so it defines the term anthropogenic on the basis of scientific definitions that distinguish natural processes from those caused by humans. Conventions for reporting to the UNFCCC are more practical – geographical demarcations that involve counting trees, for example, are often easier to make than process-based classifications.

The Global Carbon Budget report[9], published annually, tracks the progress of emissions, and its authors have already begun to translate between the two definitions. They estimate that approximately 7 gigatonnes of CO_2 are absorbed each year by natural sinks on managed land. Land-use change is therefore reported as a net sink according to NGHGI accounting, whereas it is still a net source by the IPCC definition – and this discrepancy could grow over time.

Gidden *et al.* went beyond current emissions, and instead investigated how this mismatch would play out in future scenarios through to 2100. To do so, they proposed a translation approach that aligns UNFCCC reporting with emissions scenarios set out by the IPCC. The method enables nations to update and refine their benchmarks and targets so that they can report a true net zero – one that is consistent with the IPCC goals of stabilizing the climate, but that can be tracked using NGHGI conventions.

Is Gidden and colleagues' approach perfect? Sadly, no – the quantification still contains numerical uncertainties, because there are unknowns about how some natural processes work and how they will change during the twenty-first century. The challenge for scientists is to reduce these uncertainties and provide the required level of precision. This will require that land-use information be incorporated into emissions scenarios at increasingly finer scales to make them relevant to all nations. Negotiators will also have to convince nations to agree to targets that seem more ambitious than those already in place under UNFCCC guidelines. Importantly, the new targets are not actually more ambitious than those originally set out by the IPCC, but differ only in the way that they are interpreted.

Although this story is far from resolved, Gidden and colleagues' study succeeds in both clarifying the issue and proposing a way forwards. The IPCC definition of net zero is necessary for stabilizing the climate – this much is undeniable. But providing a way of translating this definition into the language used in on-the-ground monitoring is an essential service, and one that will smooth the path towards this goal. Ultimately, no amount of creative accounting should cloud the fact that the burning of fossil fuels must come to an end. Humanity cannot 'offset' its way out of the climate crisis, but at least there is now a way to better track progress.

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Evolution

Landscape's overlooked role in steering biodiversity

Alexandre Pohl

Scientists have long sought to understand what drives biodiversity changes. A study unifies ideas about marine and terrestrial biodiversity in one explanatory framework, pointing to physical geography as dictating life's trajectory. **See p.115**

On page 115, Salles *et al.*[1] present numerical simulations of changing continental landscapes during the past 540 million years, representing the high-resolution changes in surface elevation (topography) on land and the associated sedimentary fluxes resulting from the effect of interactions between climate and plate tectonics on landscape. In the simulations, the flux of sediments generated by the erosion of the continents and then delivered to the oceans mimics the pattern of long-term changes in marine biodiversity reconstructed from fossil data, and simulated sediment cover on the continents correlates with plant biodiversity on land. These results suggest that landscape dynamics modulates the number of species that Earth can support (carrying capacity), and ultimately has dictated the evolution of biodiversity in the oceans and on the continents over geological ages. In this way, the results reconcile, for the first time, the histories of marine and terrestrial biodiversity in a single theory.

Reconstructions of the evolution of marine biodiversity on Earth, based on the compilation of palaeontological data, date back to a key publication[2] in 1981. Sampling and preservation biases in compiled fossil data have since been reduced and trends refined, and some biodiversity patterns seem robust (Fig. 1a). These include a strong increase in marine biodiversity during the Cambrian and Ordovician periods (539 million to 444 million years ago), stabilization during the second part of the Palaeozoic era (444 million to 252 million years ago), a large drop in biodiversity 252 million years ago at the boundary between the end of the Permian and start of the Triassic periods – corresponding to the largest mass extinction ever – and a subsequent rise to unprecedently high levels during the Mesozoic and Cenozoic eras (252 million years ago to today).

Plants on land showcase a completely different story. Broadly, the rate at which their biodiversity increased did not begin to change until the start of the Devonian period, around 420 million years ago – more than 100 million years after this change began in the oceans (Fig. 1b). Many hypotheses have been put forward to explain these temporal trends but there is no consensus, and most previous work considered marine and terrestrial biodiversity separately.

Salles and colleagues' model represents the interplay between tectonics and climate, which together drive the evolution of landscape – valleys, mountains and rivers – on our planet. Their model is driven by

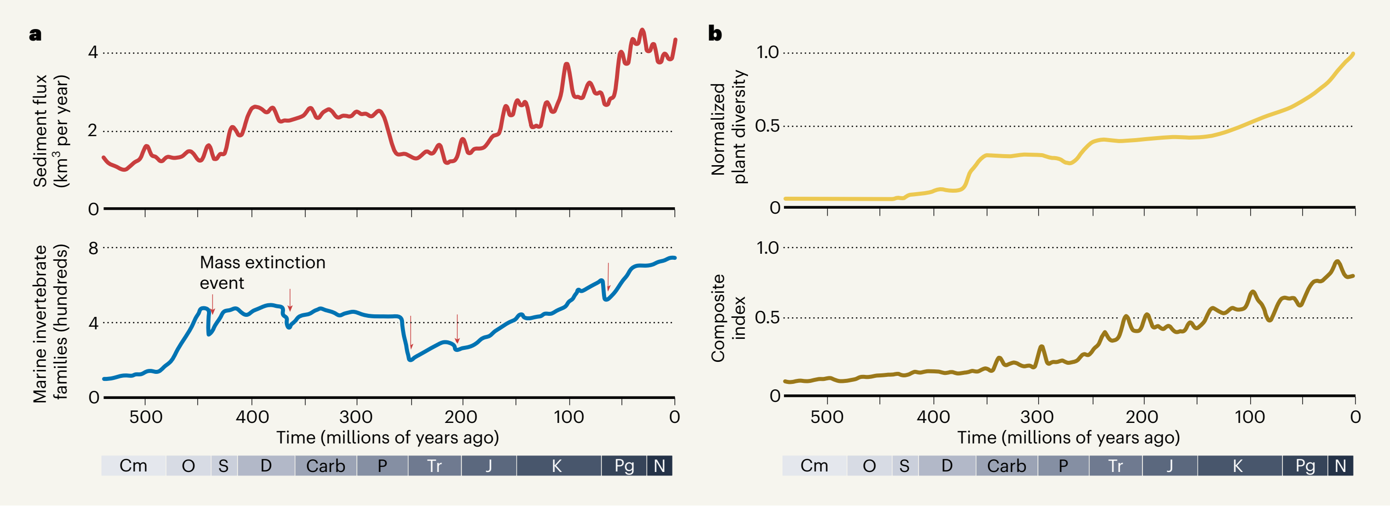

Figure 1 | Simulated landscape changes and the corresponding biodiversity changes. Salles *et al.*[1] simulated landscape dynamics over the past 540 million years and demonstrate that landscape changes might have driven the evolution of biodiversity in the oceans and on land. **a**, The simulated flux of sediments generated by the erosion of land-based rocks and delivered to the oceans correlates strongly in time with the level of biodiversity of marine invertebrates as reconstructed from fossil data[8]. Some drops in sediment flux have been followed by mass extinctions. **b**, To assess landscape effects on terrestrial plant biodiversity as tracked using fossils, the authors designed a simple metric, termed the composite index, to represent sediment cover on the continents and landscape variability (heterogeneity). Changes in the value of this index mirror long-term trends in land-plant diversity[9]. The indicated periods or eras are Cm, Cambrian; O, Ordovician; S, Silurian; D, Devonian; Carb, Carboniferous; P, Permian; Tr, Triassic; J, Jurassic; K, Cretaceous; Pg, Palaeogene; N, Neogene.