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The disquieting theories of modern physics, and a stealthy attack from an inconspicuous fish.

100 years ago

The problems of physics are manifold, and tend to increase in number and in difficulty. Fifty years ago there was a general feeling that we had only to proceed steadily in the application of familiar dynamical principles to explain all the phenomena of inanimate nature ... How different is the position to-day! ... The outstanding problems of our time, that of radiation on one hand and of atomic structure on the other, have been at least partially solved by the electro-magnetic theory of Clerk Maxwell and the electron theory which owes so much to his successors at the Cavendish Laboratory. But the still greater problem of relating these theories satisfactorily to one another and to the disquieting results embodied in the modern theories of quanta and relativity still awaits the revealing power of the master mind.

From *Nature* 4 August 1923

150 years ago

The John Dorée ... although of shy and retiring habits, has already yielded many points of interest in connection with its life history. The ordinary position assumed by this fish is the neighbourhood of the some projecting rock near the bottom of its tank, and ... it is only when on rare occasions it rises high in the water, that the beautiful mechanism that guides its movements can be appreciated. It may then be seen that the only organs called into action are the narrow and delicate membranes of the posterior dorsal and anal fins, each of which vibrates in a similar manner to the single dorsal of the pipefish; the long filamentous first dorsal, pectorals, ventrals, and caudal fins meanwhile remaining perfectly motionless. Thus this wary fish, with an almost imperceptible action, silently and stealthily advances upon its intended prey, engulphing it in its cavernous mouth almost before the hapless victim is aware of its enemy's approach.

From *Nature* 31 July 1873

Environmental science

A call to reduce the carbon costs of forest harvest

William R. Moomaw & Beverly E. Law

Economic modelling of the global carbon cost of harvesting wood from forests shows a much higher annual cost than that estimated by other models, highlighting a major opportunity for reducing emissions by limiting wood harvests. **See p.110**

Forests accumulate and store vast amounts of carbon dioxide from the atmosphere and protect biodiversity[1], giving them a defining role in controlling the global average temperature. By contrast, human activity typically increases carbon emissions to the atmosphere and diminishes species populations and diversity. Nowhere is this distinction more obvious than in the harvesting of wood from forests, but the carbon cost of this practice has been overlooked – until now. On page 110, Peng *et al.*[2] report the true carbon cost of wood harvests, which have reduced more carbon storage in vegetation and soils than any other practice except agriculture[3,4].

The authors estimate that emissions from wood harvests will add 3.5 billion to 4.2 billion tonnes of CO_2 to the atmosphere each year between 2010 and 2050. This estimate approaches the increase in emissions expected to result from land-use change as a result of the expansion of agriculture. To determine forest carbon emissions by tracking the life cycle of harvested wood, it is essential to quantify the carbon stocks in forest ecosystems and to understand how they change with harvests. It is also crucial to quantify emissions associated with the decay and combustion of residues left at the harvest site, and the decay of wood products in landfill, as well as emissions from the combustion of harvest residues at timber mills[5].

"Converting mature forests to young forests results in a considerable loss of carbon stocks."

In practice, however, many people estimate carbon cost using an approach known as net accounting, which offsets carbon emissions from one source to another. For example, fossil-fuel emissions are commonly offset by the carbon sink provided by forest ecosystems. Forest-harvest emissions are similarly offset by crediting the growth of forests in other locations. But net accounting of forest stocks has been shown to undervalue the importance of actual increases in these stocks[6]. Peng *et al.* describe several forest carbon-offset systems that have been used that allow forest-harvest emissions to go uncounted.

The authors make the essential point that carbon costs from harvested forests are substantially underestimated by the common practice of counting offsets from forests growing elsewhere. The authors consider different scenarios for the future supply and demand of wood, and use them to establish a carbon-cost accounting system that discounts the value of future carbon emissions and removals by using a common rate. In this scheme, a tonne of carbon emitted in one year is valued 4% higher than the same amount emitted the following year – a discount designed to account for the future carbon value of recovering harvested forests.

However, the authors do not consider several findings[7–9] that older forests continue to accumulate substantial amounts of carbon. Indeed, in mature forests that contain trees of different ages, the largest trees hold a disproportionately large amount of the carbon: a 2018 survey of 48 forests found that the largest 1% of trees held half the above-ground carbon[10].

Peng *et al.* argue that harvested forests regain lost carbon quickly because they grow faster than forests that have not been harvested. However, this doesn't affect the outcome. Converting mature forests to young forests results in a considerable loss of carbon stocks through harvesting, even when carbon storage in wood products is included, as the authors make clear, and future carbon stocks will always be less than those retained if no harvest occurs. Modelling has shown previously that the density of carbon expected to be stored in a mature unharvested forest is much higher than that in a mature harvested forest 120 years after harvest – even when the carbon in wood products is combined with the carbon storage after harvest[8].

Wood harvests are increasingly used as a

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Figure 1 | The felling of giant ancient cedars in the Caycuse region in western Canada.

source of bioenergy, for electricity and for community and large commercial heating systems (for example, Drax power station, the largest in the United Kingdom, sources 69% of its wood fibre in the United States and 11% in western Canada; go.nature.com/3ptahnk). Burning wood for both of these uses is often mistakenly claimed to be carbon neutral. In 2020, global bioenergy emissions for heat and electricity generation were about 1.7 billion tonnes of CO_2, which is 40–50% of the projected annual emissions from global wood consumption between 2010 and 2050 (refs 2, 11, 12). It is not clear whether all modern bioenergy emissions are accounted for in global estimates of carbon emissions.

In 2014, the Intergovernmental Panel on Climate Change (IPCC) found that the perception that bioenergy is carbon neutral was based on a misinterpretation of the guidelines for how greenhouse-gas emissions are calculated[13]. Many European countries import wood pellets from North America and say that they generate zero emissions from burning them because the emissions occur in a different location from where the wood was harvested. One of the authors of the paper by Peng *et al.* identified this loophole in 2009 (ref. 14). Yet several calls from scientists to fix this carbon-accounting problem have been ignored. Instead, a massive and growing industrial harvest, along with increasing numbers of wildfires, has turned Canada's managed forests, most of which are in the west of the country (Fig. 1), from a net sink to a net source of CO_2 emissions[15].

To ensure that reduced harvests and increased forest growth lower the carbon cost of forests, there must be carbon-management practices and accounting rules that lead to substantial carbon accumulation and storage. To implement an effective policy for reducing forest harvests, existing carbon stocks, as well as their annual change and harvest-related emissions, must be accurately measured, verified and reported. The current system of national self-reporting has proved inadequate and would be more reliable if replaced by an independent scientific body.

Fewer harvests would mean substantially less direct CO_2 emissions to the atmosphere. Reduced harvesting would also enable 'proforestation', a term used to describe the practice of leaving forests to achieve their potential for carbon-stock accumulation without harvest. Proforestation would remove more CO_2 from the atmosphere than would reforestation or afforestation (the practice of planting trees where none grew previously)[16].

The sixth assessment report from the IPCC finds that protecting natural-forest ecosystems is the highest priority for reducing greenhouse-gas emissions[17]. Peng *et al.* would no doubt agree, but they are correct in surmising that this strategy remains underappreciated. There is hope, however, that the authors' impressive study will turn this trend around and increase awareness of the enormous potential for reducing emissions by limiting forest harvests.

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The authors declare no competing interests.

Clarification

The News & Views article ‘A call to reduce the carbon costs of forest harvest’ originally understated the IPCC’s stance on the importance of forest-ecosystem protection in reducing greenhouse-gas emissions. The authors’ affiliations have also been updated.

Clarified 4 August 2023