Comment on "The Global Tree Restoration Potential"

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Abstract

Bastin et al. (Reports, 5 July 2019, p.6448) state that the restoration potential of new forests globally is 205 Gt C, concluding that "global tree restoration is our most effective climate change solution to date", and state that climate change will drive the loss of 450 Mha of existing tropical forest by 2050. Here we show that these three statements are incorrect.

Main text

Bastin et al. (*1*) provide an assessment of the potential to expand the area of Earth allocated to forests to sequester carbon to mitigate climate change. They (i) produce a data-driven model to estimate the potential area of Earth where trees will grow, then exclude existing forest, croplands and urban areas, estimating that the remaining 900 Mha of new tree cover is the 'global restoration potential', (ii) estimate the resulting carbon sequestration from foresting this area is 205 GtC, (iii) suggest this will offset two-thirds of the "global anthropogenic carbon burden" making it the "most effective climate solution to date", and finally, (iv) extend their spatial model of restoration potential in time showing a net 233 Mha decrease in global tree cover by 2050. We consider parts (ii)-(iv) fundamentally flawed.

The stated 205 GtC restoration potential is 0.22 GtC Mha^{-1} new forest cover, double previously published estimates (*2*-*5*). This anomaly is not noted by the authors (*1*). Four alternative approaches show that this number is almost certainly too high:

1. Anthropogenic land-use change, since 1750, has emitted 200 GtC, suggesting it is highly unlikely that restoring only a fraction of previously deforested land will itself sequester 205 GtC (*5*). The 900 Mha Bastin et al. suggest restoring is 39% of once tree-covered land (*1*), hence historical evidence suggests restoring this proportion of it would lead to 78 GtC uptake. Add the fraction of the 200 GtC land-sink since 1750 attributable to the 900 Mha (14% of once tree-covered land and today's existing forests), and from first principles we expect 107 GtC uptake from restoring 900 Mha new tree cover (0.12 GtC Mha^{-1}).

2. Using a fully coupled climate model to restore 100% of agricultural land (*2*) predicts 240 GtC uptake on 2020 Mha land (0.12 GtC Mha^{-1}). This converts to 107 GtC for restoring 900 Mha.

3. Using mapped restoration areas regenerating to climatically supportable carbon stock levels (*3*) results in 108 GtC sequestered over 900 Mha (0.12 GtC Mha^{-1}).

4. A mapping exercise that identified restoration areas, with no economic constraints and published sequestration rates gave a median estimate of 89 GtC when scaled to 900 Mha (*4*) (0.10 GtC Mha^{-1}).

While Bastin et al. use 'tree cover area' as their metric, this is directly comparable to the above 'land area' estimates, because their methods account for this, as, for example, 10% tree cover is only 10% of the per ha carbon sequestration. These four published estimates above are similar, with a mean of 103 GtC (range, 89-108), just 50% the Bastin et al. estimate.

Bastin et al.'s anomalous result arises because their multiplication of tree cover area by mature ecosystem carbon stock levels is incorrect. Firstly, they assume, incorrectly, that soil carbon stocks are zero prior to restoration. The original carbon density values used in (*1*) show that 37-86% of the carbon sequestration in each vegetation class is new soil carbon, a total of 113 GtC. This is not credible: it is equivalent to all the soil organic carbon lost globally since the advent of farming, ~116 GtC (*6*). Critically, when converting grassland or pasture to tree covered land -- the majority of the new tree cover (*1*) -- meta-analyses show no overall trend in soil carbon stocks (*7, 8*). Alternatively, if the global average 3.6% loss of soil organic carbon was assumed to return to these soils that would add 4 GtC, not 113 GtC as Bastin et al. claim. Thus, the total sequestration, when accounting for the prior existence of carbon in soil, is ~96 GtC, in line with published estimates.

Bastin et al. secondly assume that live stem, leaf, root, and necromass are all also zero prior to restoration. This is not correct: all of the 900 Mha they highlight as available has plants growing on it, and a significant proportion will have some trees already. Carbon removed from the atmosphere by restoration is only that added to the system from new additional vegetation growth. To illustrate the likely magnitude of this error, a recent restoration potential analysis showed 42.1 GtC uptake from restoring 350 Mha of forest, in addition to the 10.6 GtC already in biomass on the land prior to restoration (*3*). Using the Bastin et al. method, sequestration would thus have been over-reported by ~25%.

The third Bastin et al. assumption is of no impact of future environmental change on forest carbon stocks. Typically higher atmospheric CO_2 concentrations increase carbon stocks more than higher temperatures and altered rainfall reduces it (*9, 10*). Given the intrinsic uncertainty of future emissions, this impact could be as low as ~7% under low-emission scenario (*3*), or as high as ~20% increase under a mid-range scenario for the tropical forest biome (*11*). Assuming the latter and taking all three biases into account (initial soil, initial biomass, changing environment), ~92 GtC is expected to be sequestered in 900 Mha new forest cover (92 GtC on the land after restoration, minus 23 GtC already on the land, plus 4 Gt added to the soil, plus 19 Gt added from the changing environment). This corrected 92 GtC values is similar to the four independent sequestration estimates detailed above, but is less than half the Bastin et al. estimate.

The authors then compound their overestimate of the importance of forest restoration by asserting that “reaching this maximum restoration potential [205 Gt] would reduce a considerable proportion of the global anthropogenic carbon burden (~300 GtC) to date.” This 67% reduction is not correct. Human actions have added 640 GtC since 1750, thus 205/640 is 32%. The authors appear to have confused the increase in atmospheric carbon dioxide concentration since 1750, with total anthropogenic emissions. The difference is because ~55% of anthropogenic carbon dioxide emissions were removed from the atmosphere into land and ocean sinks. Reversing the atmospheric increase via restoration concomitantly weakens the sink strength (*2, 5, 12*). Thus overall, restoration over 900 Mha is ~100 GtC, which would reduce the anthropogenic burden by ~15% (i.e. [100*0.45]/300 from an atmospheric perspective, or 100/640 from an emissions perspective), not ~67% as Bastin et al. claim. Furthermore, 15% overestimates the climate impact of Bastin et al’s restoration potential, because 25% of the new tree cover is in tundra and boreal regions, where warming from forests’ lower surface albedo can offset the cooling from new carbon uptake (*13*).

Bastin et al. state in their abstract that "[our study] highlights global tree restoration as our most effective climate change solution to date." This statement is not supported by the evidence provided. Furthermore, such a statement can never be supported because, (i) in physical terms, keeping fossil carbon in its original geological storage is self-evidently a more effective solution to climate change than releasing it and capturing it later in trees, (ii) allowing trees to grow where they once grew is largely merely replacing carbon that was previously lost through land-use change, and so does not address fossil fuel emissions, and (iii) sequestering ~100 GtC into new forests is equivalent to just 10 years of current emissions clearly showing that forest restoration is of lower importance than rapidly reducing fossil fuel emissions.

Finally, Bastin et al. model the future, concluding that “global potential canopy cover may shrink by ~223 million hectares by 2050, with the vast majority of losses occurring in the tropics.” The authors state that their results are, “in stark contrast to most current model predictions", but give no explanation for this. The reason is that they first parameterise an environment-tree cover association in space for the recent past, and then apply it over time into the future, giving an erroneous result. This arises because there are no current areas of Earth today that are as hot as will exist in the core wet tropics in 2050. Thus, when 2050 climate output shows higher temperatures in areas of current tropical forest, the Bastin et al. machine learning model fills in the tree cover from areas with the closest match from today – but these are open forest and savanna areas, that are also considerably drier than climate models predict for future tropical forest areas. This upper temperature-limit problem is a well-recognised error within bioclimatic envelope-type modelling (*14*). Thus, while the intact Amazon carbon sink is declining there is no hint of a decline in canopy cover (*15*) and a switch, due to climate change alone, in the absence of deforestation and logging, which were not modelled, to swathes of open forest within the next 30 years is highly unlikely, even under the most pessimistic of climate-driven vegetation models (*11*).

One further contributory reason why the 2050 results that Bastin et al. report are in "stark contrast" to other models is because their spatial correlations exclude any impact of rising atmospheric CO_2. Given that nowhere on Earth today has 2050-level CO_2 levels, their machine learning approach is not an appropriate approach. Tropical forests' response to global change is the net of a negative impact of high temperatures, a positive impact of rising CO_2 and the impacts of any changes in rainfall or its distribution (*9*). The pivotal role of carbon dioxide for photosynthesis is well known, evidenced from theory, observations and experiments (*9*). The decision to ignore this evidence means the reported net 46 GtC loss from forest cover by 2050 is also incorrect.

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