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Comment on "The global tree restoration potential"

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Bastin *et al.* (Reports, 5 July 2019, p. 76) claim that 205 gigatonnes of carbon can be globally sequestered by restoring 0.9 billion hectares of forest and woodland canopy cover. Reinterpreting the data from Bastin *et al.*, we show that the global land area actually required to sequester human-emitted CO_2 is at least a factor of 3 higher, representing an unrealistically large area.

Bastin *et al.* (*1*) modeled the global potential tree coverage and found that there is room for an extra 0.9 billion ha of canopy cover, which could store 205 gigatonnes of carbon (GtC) in areas naturally supporting woodlands and forests. The IPCC modeling of the upper limit from pathways that could limit global warming to 1.5°C by 2050 (*2*) is 1 billion ha. We note that Bastin *et al.* do not consider forest rotations or biomass accumulation over time. Assuming that the IPCC model represents 30 years of C sequestration after tree restoration, we estimate Bastin *et al.*'s average global forest sequestration rate to be 6.8 GtC $year^{-1}$ (= 205 GtC/30 years), or 7.6 tC ha^{-1} $year^{-1}$ on 0.9 billion ha. Table 1 lists examples of realistic growth rates by biome found in the literature (*3*–*15*), with the global average forest sequestration rate being 2.31 tC ha^{-1} $year^{-1}$. Thus, the Bastin estimate for sequestration of 7.6 tC ha^{-1} $year^{-1}$ is greater by approximately a factor of 3.2 (= 7.6/2.31), based on published research from flux towers and forest inventory plots across key global forest biomes (Table 1). In other words, the estimate of 205 GtC by Bastin *et al.* would actually require 2.88 (= 3.2 × 0.9) billion ha, and not 0.9 billion ha, to have an even chance of limiting warming to 1.5°C.

In addition, the Bastin *et al.* estimate can be shown to overestimate the "remaining budget" of 158 GtC calculated by the IPCC. According to the IPCC, 158 GtC forms the threshold to accumulated atmospheric CO_2 for creating an even chance (medium confidence) of limiting global warming to 1.5°C by 2050 on 1 billion ha. The Bastin *et al.* estimate of the "remaining budget" is 205 GtC on 0.9 billion ha, which is 30% higher than the IPCC (= 205/158) target for 1 billion ha. How realistic is restoration on such a scale? An area of 2.88 billion ha is approximately equivalent to the area of Africa, 3 times that of the United States, or 115 times that of the United Kingdom.

The Bastin *et al.* methodology further overestimates global tree restoration potential by assuming that tree cover in protected areas (PAs) is a proxy for the maximum potential canopy cover for that biome. This premise appears optimistic because of the following issues:

1) The reversibility principle of the IPCC ruled that forests established after 1989 (i.e., <30 years ago) cannot be counted as restored forests; this rule was agreed on to discourage land owners from cutting down trees and then claiming carbon credit payments for the "restoring" forest (*16*).

2) Herbivores and browsers—including insects—are ecological engineers stopping huge areas of natural grasslands and savannas from converting to forest (*17*).

3) Disturbance within PAs is not considered; for example, insect attack or wildfire reduces forest biomass accumulation (*18*).

4) Many biomes are not represented within PAs because of historical land tenure and land use planning decisions.

The claim of Bastin *et al.* that 900 million ha of global forest and woodland could potentially be restored is not supported by our analysis, if we adopt the IPCC modeling of the upper limit from pathways that could limit global warming to 1.5°C by 2050 (*2*). This is especially the case when we consider that humans have deforested 13 million ha annually for at least the past three decades, and that this deforestation continues despite concerted efforts and substantial financial investment to reduce it.

The seemingly good news in Bastin *et al.* requires an enormous land area. We estimate that the global land area required to sequester human-emitted CO_2 is at least a factor of 3 higher than estimated by Bastin *et al.* As much as we would like to embrace the central conclusion of Bastin *et al.* that ecosystem restoration is "one of the most effective solutions at our disposal to mitigate climate change," we conclude that the emerging global political myth of massive tree planting and restoration as a panacea for global warming requires an unrealistically large area. Although tree

planting should be welcomed, curbing emissions appears to be the key, albeit politically challenging, action.

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Table 1. Average carbon accumulation for different forest types. Note that the multiple values and/or ranges given for C production are as stated in the original references.

Type of forest	C production (tonnes ha^{-1} $year^{-1}$)	Mean tonnes ha^{-1} $year^{-1}$	Reference
Boreal forest	1.0	1.00	(*3*)
Boreal forest	0.2, 0.4, 0.75	0.45	(*4*)
Boreal forest	0.025–0.07; 0.025–0.09	0.05	(*5*)
Temperate forest	1.8–3; 3.6–3.9	3.08	(*6*)
Temperate forest	2.628	2.63	(*7*)
Savanna	2.65–5.5; 0.65–1.50	2.58	(*4*)
Savanna	0.38	0.38	(*8*)
Tropical dry forest	1.8–3.3	2.55	(*9*)
Tropical dry forest	3.36–4.05	3.70	(*10*)
Humid tropical forest	4.2–6.3	5.25	(*11*)
Humid tropical forest	1.06–1.73	1.40	(*12*)
Humid tropical forest	0.74–2.75	1.75	(*13*)
Plantation	2.4–2.6	2.50	(*14*)
Plantation	5	5.00	(*15*)
Mean of all forest types		**2.31**	

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