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LETTER

How feasible are global forest restoration commitments?

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Abstract

Numerous countries have made voluntary commitments to conduct forest landscape restoration over millions of hectares of degraded land in the coming decade. We consider the relative likelihood these countries will achieve their restoration commitments. Across countries, the area committed to restoration increased with existing forest and plantation area, but was inversely related to development status, with less developed countries pledging more area. Restoration commitments are generally large (median: 2 million hectares) and will be challenging to meet without the wholesale transformation of food production systems. Indeed, one third of countries committed >10% of their land area to restoration (maximum: 81%). Furthermore, high rates of land cover change may reverse gains: a quarter of countries experienced recent deforestation and agricultural expansion that exceeded their restoration commitment area. The limited progress reported by countries, and the sheer scale of commitments, raises serious questions about long-term success, especially absent necessary monitoring and management plans.

KEYWORDS

biodiversity conservation, Bonn Challenge, carbon storage, deforestation, forest landscape restoration, longevity, persistence, REDD+, reforestation, sustainable development

1 | INTRODUCTION

Although tropical forests are being lost at a rate of 15.8 million hectares a year (Weisse & Goldman, 2018), temperate forest area is increasing (Keenan et al., 2015) and more and more countries are voluntarily pledging to restore vast tracts of degraded land. National pledges to the Bonn Challenge and the UNFCCC Paris Accords, and the forthcoming UN Decade on Ecosystem Restoration, have brought forest landscape restoration into the center of the global discussion on ways to combat climate change, prevent species extinctions, and improve rural livelihoods (Bastin et al., 2019; Griscom et al., 2017; IUCN, 2018; Suding et al., 2015; Verdone & Seidl, 2017). The Bonn Challenge, launched in 2011, aims to bring 150 million hectares of the world's deforested and degraded land into the process of restoration by 2020, and 350 million hectares by 2030 (GPFLR, 2019). Bonn commitments already exceed 170 million hectares, and in the last decade, other voluntary national restoration targets totaling 230 million hectares have been pledged in response to various conservation policy instruments (GPFLR, 2019; IUCN, 2018). The majority of targets come from developing countries in the global South, and funding for forest conservation and restoration is set to rapidly increase in the next decade, although it remains dwarfed by subsidies for forestry and agriculture (Climate Focus, 2017).

Several authors have weighed in on the policies that underlie global restoration commitments, pushing for tighter integration between science and policy (Chazdon et al., 2017; Suding et al., 2015), more comprehensive and measurable requirements for meeting commitments (Mansourian, Stanturf, Derkyi, & Engel, 2017), and changes in restoration objectives. Proposed changes include limiting expansion into savannas and grasslands (Veldman et al., 2015), prioritizing natural regeneration of forests (Lewis, Wheeler, Mitchard, & Koch, 2019), and optimizing the quality and persistence of restored habitat, rather than focusing solely on restored area (Mansourian et al., 2017; Reid, Fagan, Lucas, Slaughter, & Zahawi, 2019; Stanturf, 2015). The studies that have examined the potential impact of global restoration on climate change project that current commitments would lead to extensive carbon sequestration, though commitments will come in part at the cost of agricultural land (Bastin et al., 2019; Bernal, Murray, & Pearson, 2018; Griscom et al., 2017; Wolff, Schrammeijer, Schulp, & Verburg, 2018).

All these analyses presuppose that current forest restoration commitments are largely achievable. However, few countries have met their Bonn commitments thus far, with only two completed (Pakistan and the United States; GPFLR, 2019) and limited reporting on progress in most other countries (but see Crouzeilles et al., 2019; Dave et al., 2019). Despite Bonn Challenge commitments for 2020 exceeding 94 Mha, signatory parties collectively face a 54% deficit in the area committed (43.7 Mha) to meet their goal (Dave et al., 2019). Although a wide variety of activities qualify as forest landscape restoration under these initiatives, all require coordinated changes in the management of forests and farms across large areas. And though restoration interventions are often conceptualized as distinct from interventions to address deforestation and agricultural expansion (NYDF Assessment Partners, 2019), the same structural factors that led to the need for restoration could imperil restored ecosystems. For example, secondary forests in general have a short lifespan across tropical Latin America, with annual reclearance rates of 3–23% (Reid et al., 2019).

In this paper, we consider the relative likelihood that countries will achieve their voluntary national restoration commitments. We ask three related questions: First, is the amount of land committed related to a country's demonstrated success in restoring forested landscapes and implementing sustainable development? Second, for the small sample of countries that have publicly reported progress on commitments, is progress related to development level or other risk factors, like deforestation? Third, which countries will likely face the greatest challenges to meet their commitments and maintain restored land into the future? For this question, we focus on the feasibility of commitments given current land use patterns, the likelihood of restored forests persisting given land use pressures and government effectiveness, and how well countries have performed on meeting other sustainable development goals.

2 | METHODS

2.1 | Source data

To quantify country-level commitments, we collated available data on the area pledged to the Bonn Challenge ($n = 47$, excluding the eSwatini microstate; GPFLR, 2019) and to national restoration targets (NRTs; $n = 36$; IUCN, 2018). NRTs are voluntary national commitments reported to international programs, including the UNFCCC, REDD+, and others. Countries did not distinguish between area pledged to Bonn or NRTs, so the greater of the two areas was used ($n = 62$; analyses using Bonn-only commitments showed similar results). To quantify progress, country-level data on total area restored ($n = 12$ countries reporting) were gleaned from public reports and press releases (Borah, Bhattacharjee, & Ishwar, 2018; Dave et al., 2019; GPFLR, 2019; IUCN, 2018).

To assess restoration commitments, progress, and the likelihood of completion, we combined country-level data from several public sources (see Tables S1 and S2). These included data on forest, agriculture, and tree plantation cover; agricultural production and trade; and socioeconomic and governance indicators. If variables had pairwise correlations >0.8, theoretical considerations were used to omit one from statistical analyses (Table S1).

2.2 | Commitment data analysis

Eighteen potential correlates of country commitments were identified to characterize recent land use change and economic development trends (Table S1). Bonn Challenge commitments are broad and can be met via restoring degraded forest, planting or letting forests regrow, or planting trees in agricultural areas (Dave et al., 2017). Thus, we hypothesized that countries would commit greater areas if they had large forested areas (a proxy for degraded forest area), large agricultural areas, large areas of tree plantations and permanent tree crops (e.g., agroforestry), recent increases in forest cover, and/or declines in agricultural area. Given the expense and opportunity costs of restoration (Latawiec, Strassburg, Brancalion, Rodrigues, & Gardner, 2015; Strassburg et al., 2019), we also hypothesized that countries would commit greater areas if they were wealthier and more urbanized (higher GDP per capita, lower GDP growth, lower total population growth, lower rural population proportion, and lower population density), less dependent on export agriculture (net agricultural trade, percentage of agriculture production exported; DeFries et al. 2010), and closer to achieving goals tied to eliminating

extreme poverty (United Nations, 2015; e.g., a lower proportion of deaths from unsafe water [SDG Goal 6] or people living in poverty [SDG Goal 1]).

Country commitments were assessed using two independent but complementary approaches: regression trees and multiple linear regression. To normalize regression residuals, the response variable was log-transformed, and to address the wide range in land area between countries, models were fit with and without log-transformed area variables. Regression trees were run 1,000 times with a control parameter of 0 and 10-fold cross-validation; resulting mean values of the cross-validated error matrix indicated no need for pruning. The full, all-predictor multiple linear regression model underwent variable selection using a stepwise AIC approach (both forward and backward). The final stepwise linear regression model had four predictors with low multicollinearity, with acceptable tolerance values and condition indices (Table S3).

2.3 | Potential risk data analyses

We assessed potential risks in achieving restoration commitments using 12 indicators, grouped into three broad categories: (a) commitment feasibility, (b) the likelihood of maintaining restored forests (i.e., deforestation drivers), and (c) a record of effective governance (see Table S2). To predict Bonn Challenge progress in the reporting subset of countries ($n = 12$; Table S4), the percentage of original commitment achieved (maximum 100%) was regressed against the country-level mean of the 12 risk indicators. Prior to analysis, achievement percentage was adjusted for differing year-effort and arcsine transformed, and risk indicators were percentile rank normalized. Additionally, risk indicators were qualitatively compared across all countries ($n = 62$; Table S5).

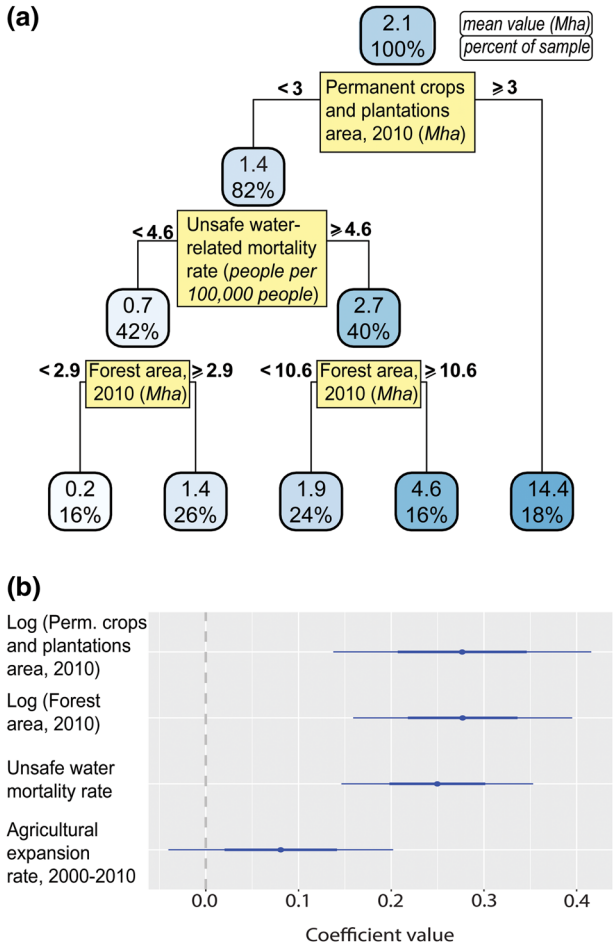

FIGURE 1 (a) Rpart regression tree for predicting the area committed to restoration (Mha); log-transformed area units are converted for interpretation. Split values for predictor variables are shown, with the mean area committed and percentage of countries sorted into the resulting nodes. See Table S1 for details on predictor variables. (b) Coefficient means and standard errors for a stepwise multiple linear regression predicting the logarithm of area committed to restoration ($p < .001$, $r^2 = .63$). Predictor variables have been standardized so that an effect size of 1 is one standard deviation

3 | RESULTS

In all analyses, countries with larger forest areas, larger areas of plantations and permanent tree crops, and greater proportional water-related mortality pledged greater areas for restoration (Figures 1 and 2). The total area committed to restoration across countries was predictable by both regression tree (mean cross-validated $r^2 = .20 \pm .13$) and stepwise linear regression ($p < .0001$; $r^2 = .63$; Figures 1 and 2). The stepwise linear regression identified one additional non-significant predictor: increasing commitment area was associated with greater agricultural expansion ($p = .19$). Although model results were similar, final regression models with log-transformed area variables outperformed models with untransformed area predictor variables ($\Delta AIC = 32.2$).

Across countries, the median restoration area committed was 2 million hectares, and the median percentage of land area committed was 5.6%, with one third of countries committing >10% of their area (maximum of 81%; Figure 3 and Figure S1). Five countries have commitments larger than their total agricultural area, fourteen have commitments larger than their total forest area, and two countries (Vietnam and Rwanda) exceed limits on both counts (Figure 4). One third of countries experienced agricultural expansion or forest loss on >5% of their land area in a 15-year period (2000–2015; Figure 5), and 65% of countries have a current area of tree plantations and permanent crops that is smaller than their restoration pledge (Figure 2). Observed progress in restoration reported in the subset of 12 countries was negatively related to their mean risk indicator score ($p < .002$, $r^2 = .59$; Figure 6).

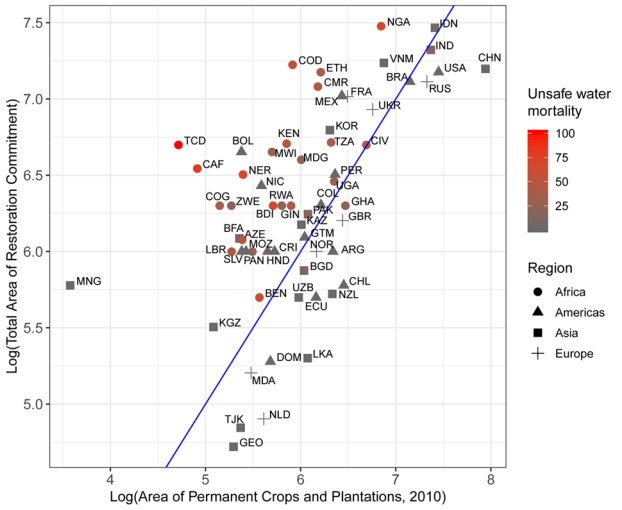

FIGURE 2 For each country, the area of land occupied by permanent crops and plantation forests in 2010 is plotted against the area of restoration commitments (both log-scale, base 10). Countries are colored by number of unsafe water-related deaths per 100,000 people, and labeled by World Bank code and region (see Table S7). The blue line represents the 1:1 line of equality between the two area variables

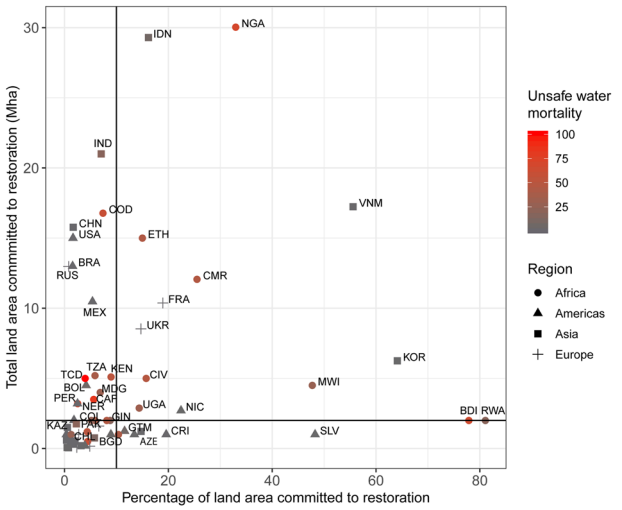

FIGURE 3 The proportion of land area potentially occupied by restoration commitments plotted against the absolute area of restoration commitments in millions of hectares, for all countries. Countries are labeled by World Bank code and region (see Table S7). The black lines mark a commitment of 10% of a country's land area (x) and 2 million hectares (y), respectively. Country labels below these arbitrary thresholds are largely omitted for clarity (see Figure S1 for inset figure)

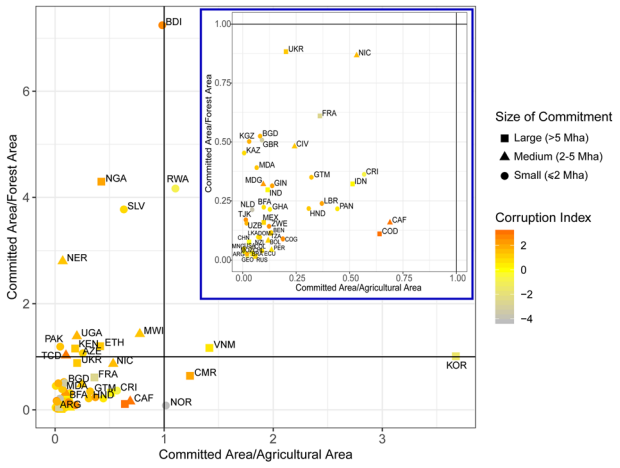

FIGURE 4 For each country, the proportion of current agricultural area that would be occupied by restoration is plotted against the proportion of current forest area that would be occupied by restoration. Points are colored by a metric of government effectiveness and corruption (Table S2; higher values = more corruption) and labeled by World Bank country code (Table S7) and size of commitment (Table S6). Thin black lines mark values greater than one, indicating that committed restoration area is greater than agricultural/forest area. Thick blue lines surround an inset for the 0–1 range for both axes

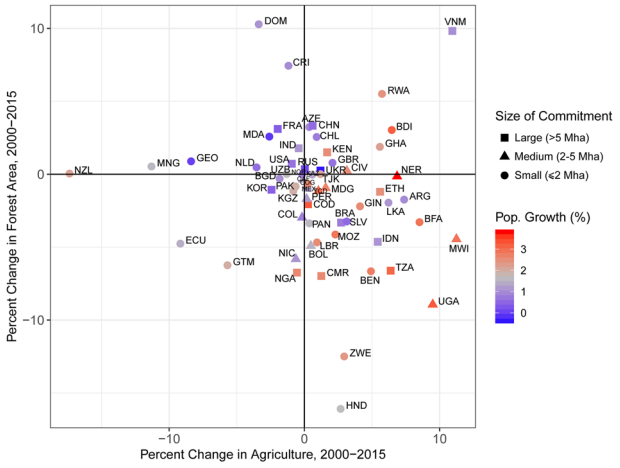

FIGURE 5 For the period 2000–2015, the change in agricultural area as a proportion of land area is plotted against the net change in forest area as a proportion of land area, for all countries. Points are colored by total population growth (2016–2017) and labeled by World Bank country code (see Table S7), and shapes indicate size of commitment (Table S6). The bottom right panel shows countries with net forest loss and net agricultural expansion

4 | DISCUSSION

As expected, larger countries with greater forest and plantation areas made larger pledges than smaller, less-forested countries—presumably due to a greater capacity and/or area for implementing restoration. But contrary to expectations, less-developed countries committed more territory to restoration than more-developed countries (Figure 2, Figure S2, and Table S6). Although these results are limited to countries that made a pledge ($n = 62$), an inverse relationship between development and restoration commitments could exist for multiple and overlapping reasons. Lesser developed countries could be: (a) taking action against the greater risks they face from climate change (IPCC, 2014) and land degradation (Barbier

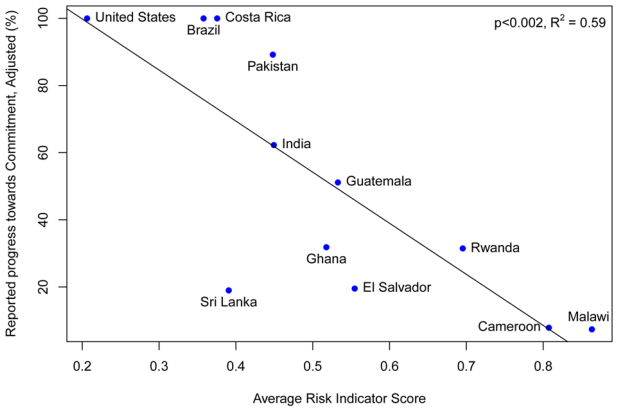

FIGURE 6 Progress toward Bonn restoration pledges for a subsample of early-reporting countries (see Table S4 for details), as predicted by the country-level means of the risk indicator values (after percentile rank normalization). Progress was adjusted to a standard eight years from available data; after adjustment, the United States, Costa Rica, and Brazil all met their pledges. The black line shows a linear regression fit for illustration, with the p-value and r^2 labeled from the arcsine-transformed regression

& Hochard, 2016), (b) motivated to bolster natural capital as a viable development pathway, especially given their lower costs for restoration interventions, (c) leveraging the size of their commitments to secure financial assistance from donors, or (d) not carefully considering the actions needed to complete commitments, potentially due to capacity gaps.

Many countries took on ambitious restoration commitments that, if realized, would likely necessitate substantial shifts in land use and agricultural economies. Only 22 of 62 countries took on smaller commitments (<2 million hectares and <10% of their land area; Figure 3), whereas one-quarter of countries made commitments larger than either their current forest or agricultural areas (Figure 5). Of these, six countries pledged close to 50% or more of their land area, and Rwanda and Burundi pledged >75% (Figure 3). To put this in perspective, a similar pledge by the United States would require restoring an area equivalent to the 48 contiguous states. These commitments will be challenging to meet without the wholesale transformation of food production, especially given policies that currently prioritize intensive agriculture. For example, although Rwanda's agricultural policy subsidizes woodlot planting as part of its restoration plan (MINIRENA, 2014), it also legally penalizes agroforestry and mandates monoculture production (Clay & King, 2019; Isaacs, Snapp, Chung, & Waldman, 2016).

For the smaller sample of countries that have reported Bonn Challenge progress, progress was higher in countries with a lower mean risk indicator score (Figure 6). Although this correlation may be driven by small sample size or selective reporting (and should be viewed as preliminary, pending additional data), it held across large and small countries and supports the hypothesis that potential barriers to progress, like corruption and forest loss, may impede restoration efforts. Furthermore, the three largest countries (Brazil, India, and the United States) restored the largest areas, highlighting the differences in resources and opportunities for restoration at greater scales (Table S4). For example, India restored 9.8 million of a 21 million hectare commitment, largely via tree plantations and agroforestry (Borah et al., 2018). For other countries, the early numbers reported lack details (e.g., Guatemala), assume that regrowth will persist in frontier regions (e.g., Brazil), or arise from a broad definition of landscape restoration that does not always result in additional forest area or extensive carbon sequestration (Dave et al., 2017, 2019). For example, although the United States officially reported restoring nearly 17 million hectares, only 4% (634,000 ha) consisted of newly planted forests, agroforestry, or natural regeneration, with the remainder in silvicultural treatments like thinning and prescribed burning that restore existing forests (IUCN, 2018).

Even if countries are able to fully meet stated area goals, it is not clear how long restored areas will persist. Long-term forest development is required to optimize carbon sequestration and restore habitat for many forest-associated species (Reid et al., 2017). However, we found that rates of net forest loss, population growth, and agricultural expansion were correlated across countries ($p < .01$; DeFries et al., 2010) and high on average (mean rates >1%; Figure 5), suggesting that many restored forests may be ephemeral (e.g., Müller, Rufin, Griffiths, de Barros Viana Hissa, & Hostert, 2016). As if to underscore this point, a quarter of countries experienced more recent forest loss and agricultural conversion (2000–2015) than their restoration commitment for the next 15 years (2015–2030). Progress on sustainable development goals may also foreshadow how well restoration projects will be managed. One third of countries have below-median scores on all four development indicators (water-related mortality, good governance, medical access, and rural electrification; Table S5), suggesting that completing their restoration commitments may be particularly challenging.

BOX 1 Regional restoration in Central America

All Central American countries with restoration pledges made large commitments relative to their size (8–22%; ≥1 Mha), despite broad socioeconomic differences that will make implementation more challenging for some (Table 1). For example, Costa Rica has the highest GDP per capita, a well-established policy framework that promotes reforestation (Pagiola, 2008), and recently reported completing its commitment (pending verification). At the opposite extreme is El Salvador, with the highest population density and the lowest remaining forest cover (12.6%, <1% primary; FAO, 2015). El Salvador pledged nearly half its surface area and fourfold

its existing forest cover (Figures 3 and 4). Accordingly, its commitment is primarily planned agricultural improvements (silvopasture and agroforestry), with only a fraction (<5%) pledged for forest restoration (Dave et al., 2019). Nonetheless, El Salvador initiated the UN "Decade on Ecosystem Restoration 2021–2030" proclamation, with the goal of supporting restoration efforts across countries (MARN, 2018).

BOX 2 Aid-dependent restoration in Mozambique

Mozambique has a distinct set of restoration challenges. Aid is 5% of GDP (Table 1), and Mozambique's capacity to meet its restoration commitments is dependent on donor financing, led by the World Bank. Although the government created a national REDD+ strategy to lower deforestation by 40% and restore forests (1 Mha), the nation has high population growth, a largely rural population (65%), and continued reliance on fuelwood and charcoal for energy (Table 1; 80% of households). The government's integrated landscape restoration strategy depends on engagement and cooperation with local communities that, in many cases, still lack formal recognition of customary tenure. After recent devastation from two 2019 cyclones, Mozambique is now asking for an additional $50 million from donors for reforestation of mangrove forests and cyclone-affected regions.

TABLE 1 Potential indicators of risk for a subset of 16 countries with restoration commitments. The numbers are the risk indicator values (see Table S2 for a full description of risk indicators and Table S6 for data on all countries), while the grayscale colors show the percentiles of those indicator values across all countries with restoration commitments ($n = 62$)

	Pledge (Mha)	Pledge (%)	Plantation Gap (%)	Committed Land Cover (%)	Forest Loss (%)	Ag. Expansion (%)	Pop. Growth (%)	Aid (% GDP)	Water Mortality	Unelectrified Rural (%)	People/Physician	Corruption Score
Netherlands	0.1	2.4	−10	4	−0.5	−4.7	0.6	0	0	0	3	−3.7
Georgia	0	0.8	−2	2	−0.9	−8.7	0	1.1	0	0	2	−1.3
New Zealand	0.5	2	−6	5	0	−18.1	2.1	0	0	0	3	−4
Norway	1	2.7	−2	8	0	−0.2	0.8	0	0	0	2	−4.2
Chile	0.6	0.8	−4	3	−2.6	0.8	0.8	0	0	0	10	−1.9
United States	15	1.6	−2	4	−0.7	−0.9	0.6	0	0	0	4	−2.9
Pakistan	1.8	2.3	1	5	0.8	0.2	2	0.2	20	1	10	1.4
India	21	7.1	−1	12	−1.8	−0.4	1.1	0	19	22	13	0.2
Nicaragua	2.7	22.4	20	53	5.8	−0.6	1.1	1.5	2	43	11	1.5
Mozambique	1	1.3	1	2	4.1	2.3	2.9	4.8	28	95	182	1.8
Uganda	2.9	14.4	3	20	8.9	9.5	3.3	2.5	32	82	108	1.6
Dem. Rep. of the Congo	16.8	7.4	7	11	2.1	0.3	3.3	3.2	60	100	110	3
Cameroon	12.1	25.5	22	64	7	1.2	2.6	1.4	45	79	120	2
Burundi	2	77.9	60	98	−3	6.5	3.2	5.4	65	98	385	2.6
Malawi	4.5	47.7	42	78	4.5	11.2	2.9	6.8	28	96	526	1.3

Quantile: 1.00, 0.75, 0.50, 0.25, 0.00

The risk factors analyzed here are relative—not absolute—and some countries may fulfill their commitments despite challenges such as an apparent lack of suitable land, high deforestation rates in recent years, or limited progress on prior sustainable development initiatives (Boxes 1 and 2). These risk factors also gloss over some nuanced interactions. For instance, one third of countries have electrified less than half of rural homes. Improving community access to electricity alone could reduce rural poverty and forest degradation from charcoal harvesting, regardless of whether restoration commitments are met (Cook, 2011; DeFries & Pandey 2010). Similarly, meeting restoration pledges without risking "green grabbing" will require governments to formally recognize the customary tenure that communities hold over forests and agricultural land (Fairhead, Leach, & Scoones, 2012). Still, the possibility that some countries will fall short is undeniable, and has important ramifications for climate change, biodiversity conservation, and rural livelihoods (Wolff et al., 2018).

If the costs of implementing restoration lead to an enthusiasm gap (*sensu* Stanturf et al., 2019), countries may shortcut their commitments with methods that entail minimal land-use change, such as using silviculture to restore forests degraded by logging or fire (e.g., the United States), establishing exotic commercial tree plantations (e.g., India), or promoting low-density agroforestry plantings (e.g., El Salvador). Such strategies have the potential to create a hollow victory scenario, allowing countries to claim pledge fulfillment while falling short of expectations for carbon sequestration and/or biodiversity conservation (Bastin et al., 2019; Brancalion et al., 2019). Future efforts to model the outcomes of global forest restoration will be improved by including the potential for partial fulfillment of national commitments, or fulfillment that does not result in much new habitat or long-term carbon sequestration.

To bolster and expand current restoration commitments, we call for more international engagement (e.g., Chazdon et al., 2019) and accountability. First, reporting of restoration would be aided by stricter, measurable criteria for what is considered restoration. Second, to determine which restoration policies are most effective, improved estimates of the impact and persistence of restored forests are needed, with an emphasis on measuring long-term carbon and biodiversity benefits (Chazdon & Guariguata, 2018). Finally, given the demonstrated value of restoration, international donors should increase financial and logistical support, and not just for the short-term. For example, the FAO Forest Resources Assessment could assist national restoration monitoring and capacity building efforts, and formal incentive systems could reward countries making progress toward their pledges.

Although we laud the momentum that the Bonn Challenge has generated, it was initially conceived as a mechanism to advance multiple sustainable development goals—which were themselves created so that the needs of the present could be met without compromising the needs of future generations.

Specifically, restoration commitments address REDD+, Aichi Target 15, and SDGs, which collectively aim to reduce biodiversity loss and reverse climate change and environmental degradation. Our analysis indicates that many countries potentially face significant challenges to fulfilling their voluntary restoration commitments. They may need assistance in implementing restoration synergistically to achieve multiple, lasting benefits. Otherwise, purported success may be undercut by ephemeral land-use changes or political shortcuts that represent pale facsimiles of high-quality restoration. If voluntary commitments like the Bonn Challenge fail to precipitate meaningful restoration across large areas, the UN's collective vision of a sustainable future will become less attainable.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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