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How do REDD+ projects contribute to the goals of the Paris Agreement?

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Abstract

Hundreds of projects to reduce emissions from deforestation and forest degradation and enhance carbon stocks (REDD+) are implemented globally, many by non-governmental organizations (NGOs) or for-profit companies. Yet, at the global level, the Paris Agreement focuses on jurisdictional (national and subnational) REDD+. We ask: (1) How much can REDD+ projects contribute to achieving national and international climate objectives? (2) What are the issues in integrating REDD+ projects into national carbon accounting? Our snapshot of 377 REDD+ projects covering 53 million ha in 56 countries is based on data from the International Database on REDD+ Projects (ID-RECCO) supplemented with new data on projects' accounting methods. The number of new REDD+ projects declined steadily from 45 new projects in 2011 to five in 2019. We examined 161 certified projects that started between 2007 and 2017; 96 of these could sell carbon credits in voluntary carbon markets by 2020 and spent on average 4.7 (± 2.4) years between project start and sales in voluntary carbon markets. Globally, REDD+ projects claim to reduce an average of 3.67 tCO2e/ha annually. This figure - combined with projects limited coverage - implies that projects need to be upscaled more than 40x to fulfil the potential contribution of tropical and subtropical forests towards limiting global warming to well below 2oC. Compared to the national carbon accounting methods, most projects in Colombia, Indonesia and Peru (63 of 86) use at least one different carbon accounting parameter. Carbon accounting inconsistencies across levels need to be addressed. Overall, the argument for REDD+ projects lies in the emissions reductions they can achieve, diversifying participation in REDD+ and providing non-carbon benefits to local communities, potentially leading to broader support for climate action.

1. Introduction

Reducing emissions from deforestation and forest degradation and enhancing carbon stocks (REDD+) is critical to keep global warming below 1.5 °C and can help achieve forest conservation and development co-benefits [1–3]. In the context of the 2013 Warsaw Framework of the United Nations Framework Convention on Climate Change (UNFCCC) and the 2015 Paris Agreement, dozens of countries, provinces and districts initiated jurisdictional (national and subnational) REDD+ programs [3]. Simultaneously, hundreds of local REDD+ projects have been implemented across the tropics, often by non-governmental organizations or for-profit companies and oriented to the voluntary carbon market [4–7]. These projects have modestly positive impacts for forests and people [3, 8] and provided important lessons for jurisdictional REDD+ programs. Although the role of such projects in the context of government-led REDD+ is debated, they do provide a way for multiple actors to engage in forest conservation efforts.

With the recent growth in voluntary carbon markets, opportunities for REDD+ projects to access new market-based finance and achieve greater impacts may eventually arise in the context of the Paris Agreement rulebook, finalized at the 26th Conference of the Parties to the UNFCCC in Glasgow in 2021. Emissions reduced by REDD+ projects need to be nested into jurisdictional REDD+ programs to avoid double counting.

How can REDD+ projects contribute to the new climate regime? We analyze two aspects of this question: (a) how much can REDD+ projects contribute to achieving national and global climate objectives? (b) What are the issues in integrating REDD+ projects into national scale carbon accounting?

We assess REDD+ projects globally and examine forest carbon loss and accounting in Colombia, Indonesia and Peru. These countries have many REDD+ projects coexisting with national and subnational REDD+ programs, and they have been among the most successful in attracting international finance from multilateral and bilateral results-based programs and voluntary carbon markets [9–11]. Brazil is not considered here despite having the largest area and financing for REDD+ projects because their contributions to emission reductions (ERs) is relatively well studied [e.g. 12–14].

2. Methods

2.1. REDD+ projects contributions to ERs

We assess the potential for REDD+ projects to contribute to climate change mitigation using two approaches: (a) A global snapshot describing the landscape of REDD+ projects that are currently ongoing, trends of project establishment across time, and the suitability of their locations to their objectives; (b) benchmarking ERs estimated by REDD+ projects compared to forest loss trends at the subnational and national levels globally and in Colombia, Indonesia and Peru.

2.1.1. Global snapshot of REDD+ projects

The snapshot is based on the International Database of REDD+ Projects and Programs/ID-RECCO v.4.1 [15]. Earlier versions of ID-RECCO have been used to provide a global snapshot of REDD+ projects between 2014 until 2018 (e.g. [7, 16, 17]). The ID-RECCO v.4.1 dataset we use here was updated in 2020, which—taken together with existing papers—offer a time-series view of the evolution of REDD+ project. In addition, we complement the analysis with new data on carbon project and national-level accounting methods gathered from REDD+ project documents and national forest reference emission levels (FRELs) submissions. The resulting composite dataset [18] includes 377 ongoing REDD+ projects as of December 2020. We include projects located in developing countries regardless of certification status and focus on avoided deforestation and degradation and on forest conservation (AD), afforestation/reforestation/revegetation (AR), and improved forest management (IFM). For simplicity we refer to the dominant project type, while recognizing that projects often have multiple objectives. For example, AD projects could include secondary AR objectives, and vice versa. The snapshot includes all countries with at least one ongoing REDD+ project. Parameters of the snapshot and definitions of project classification are in table 1. Some parameters are compared with a similar snapshot done in 2014 [7].

REDD+ project proponents estimate their ERs using carbon accounting methodologies accepted by the voluntary carbon market. These figures can be inaccurate and imprecise due the complexity and uncertainties in quantifying forest carbon emissions and incentives to inflate estimates [14, 19]. Despite these issues, they are built from the bottom-up, thus representing the best locale-specific estimates available.

We assessed whether projects are found in places suitable for meeting their dominant objectives. AD projects potentially avoid the most carbon emissions in forests at risk of deforestation with large carbon stock. We use historic forest emissions [20] and forest above-ground biomass [21] as proxies for these two factors, and use a clustering approach to classify AD projects in groups with similar suitability characteristics. We apply *k*-means clustering with the optimal number of clusters (four) determined by both the Elbow and the Silhouette method. The k-means clustering was executed in R with the 'cluster' package. AR projects can potentially remove the most carbon where there is high forest restoration potential [22]. Historic forest emissions, forest above-ground biomass, and forest restoration potential are available as gridded data with resolutions ranging from 30 m to 1 km, which were aggregated to 10 km resolution rasters. The 10 km raster values were then extracted at each project center point location to represent a regional estimate at the project's location. This method was chosen as we did not have specific delineated project areas for all global projects. IFM projects were excluded due to the small number of projects.

Table 1. List of parameters assessed and terms used in the global snapshot of REDD+ projects.

Parameters of the global snapshot of RED+ projects		
Parameter list	2020 vs 2014 comparison?	Spatially-explicit analysis?
Number of ongoing projects	Yes	No
Area (in ha) of ongoing projects	Yes	No
Distribution of projects and area in projects across countries, project types, certification status	Yes (across countries only)	No
Distribution of area in projects across countries, project types, certification status	Yes (across countries only)	No
Time gap (in years) between project start and sales of carbon credits	No	No
Number of project-starts by year	No	No
Emission reductions (ER) estimates per year per ha	No	No
Suitability of project locations to project objectives (AR and AD projects)	No	Yes

Project classifications and definitions	
Classification	Definition
Ongoing vs not ongoing projects	Ongoing status: Project has online activity (e.g. project website with new content, publications about the project, active social media accounts, project monitoring documents based on extensive internet search between September and December 2020) or valid carbon certification. Where online activity could not be found, project proponents were contacted for confirmation by email. If confirmation of project activity was not received within 1 month, we determined the project status could not be confirmed and therefore not ongoing.
Certified vs uncertified projects	Certified REDD+ projects with valid certification from Verra (VCS, CCBS), Plan Vivo, Gold Standard, Mata Viva, or CDM A/R as of September 2020. Uncertified projects never sought certification or sought it at one point in time but are still in the pipeline, have expired certification or withdrew from the certification process.
Dominant project type (AD/AR/Other)	Approximated by the objective that is applied on the largest proportion of the project area as described in the project document. We do not differentiate between avoided deforestation (compared to business as usual/BAU scenario) and reduced deforestation (compared to historical average).

2.1.2. Benchmarking exercises to gauge project contributions to global and national ERs

We undertake three benchmarking exercises to examine whether REDD+ projects could make a significant contribution to global and national objectives to reduce emissions. Assessments (a) and (b) use ER estimates found in project documents [18], while assessment (c) is a spatially-explicit analysis. Since REDD+ projects are neither distributed randomly nor easily replicated, these theoretical exercises are meant to gauge the magnitude of ERs from projects compared to the magnitude of the broader climate mitigation targets.

(a) The sum of ER estimates from all types of REDD+ projects is benchmarked against published estimates of the annual mitigation contribution from forest-based climate solutions in tropical and subtropical areas needed to stay below <2 °C warming [23] to gauge how much scaling up would be needed for projects to meet the estimated mitigation potential of (sub)tropical forests.

(b) The average ER yr ha^{-1} from AD projects ('project avoided emissions rate') is benchmarked against emissions from loss of above ground biomass in 2020 per ha of forest cover in 2020 ('national emissions rate') in a given location (region or country) [24]. A ratio of avoided emissions to national emissions of >1 shows that AD projects are preventing more emissions per ha than the average national rate of emissions from forest loss. This suggests that projects are designed and located such that they can make significant contributions to forest-based NDC targets. The potential for scaling up depends on whether a high ratio is primarily due to site selection in areas with high technical potential to reduce emissions or the proponent's effectiveness in realizing that potential.

(c) Forest cover loss trends of the REDD+ projects in Colombia, Indonesia and Peru are

Table 2. Methodological details of the BACI benchmarking method.

<table>
<tr><th>Detail</th><th>Description</th></tr>
<tr><td>Data source</td><td>The BACI benchmarking method uses Global Forest Change data (version 1.8), which is based on a time series analysis of Landsat satellite imagery, providing tree cover density for 2000 and annual tree cover loss for 2001–2020 [26]. Forest cover loss is based on tree cover loss in areas with a tree cover density of 25% in 2000. The time series forest cover loss data was aggregated into two periods (before and after project start).</td></tr>
<tr><td>Scope of analysis</td><td>We included ongoing REDD+ projects in Colombia, Indonesia and Peru that started between 2004 and 2018 as stated in the projects' design document, so that there was a minimum of 3 years in the before and after period ($n = 49$). We exclude IFM and other projects from this analysis because of the small numbers of these project types in the three focal countries.</td></tr>
<tr><td>BACI score</td><td>The BACI score is calculated as follows [4]:
$$\text{BACI score} = (\bar{x}_{AI} - \bar{x}_{BI}) - (\bar{x}_{AC} - \bar{x}_{BC})$$
where $\bar{x}_{AI}$ represents the average annual deforestation rate in the REDD+ project area in the period since the intervention started, as a percentage of the total forest area in 2000; $\bar{x}_{BI}$ represents the average annual deforestation rate in the REDD+ project area in the period from the start year of measurement (2001) up until the project started. Similarly, $\bar{x}_{AC}$ and $\bar{x}_{BC}$ represent the average annual deforestation rates in the comparison areas in the after and before period, respectively. We grouped the BACI scores, with the following thresholds: poor (score > 0.1), neutral (score −0.1–0.1) and good (score < −0.1).</td></tr>
<tr><td>Project boundaries</td><td>We used spatially explicit project boundaries from available KMZ files or maps in the project documentation. If not available, REDD+ project areas were represented by the most detailed spatial geography available from open data sources such as targeted administrative levels (GADM03.6[a] database for Peru and Indonesia; COD-AB[b] database for Colombia), biomes (TEOW2F[c]) or national parks (WDPA[d] 3), as summarized below.
<table>
<tr><th>Geographical delineation</th><th>Colombia</th><th>Peru</th><th>Indonesia</th><th>Total</th></tr>
<tr><td>Project level</td><td>19</td><td>12</td><td>6</td><td>36</td></tr>
<tr><td>Administrative 3 level</td><td>—</td><td>1</td><td>—</td><td>1</td></tr>
<tr><td>Biome within administrative 2 level</td><td>—</td><td>2</td><td>—</td><td>2</td></tr>
<tr><td>Administrative 2 level</td><td>9</td><td>2</td><td>1</td><td>12</td></tr>
<tr><td>National park</td><td>1</td><td>—</td><td>—</td><td>1</td></tr>
<tr><td>—</td><td>—</td><td>—</td><td>—</td><td>52</td></tr>
</table></td></tr>
<tr><td>Scale of comparison</td><td>This analysis was performed for two scales of comparison areas: (a) national level with administrative boundary of country and (b) subnational level with administrative level 1 boundaries of provinces (Indonesia), regions (Peru) or departments (Colombia) in which the projects are located.</td></tr>
</table>

[a] https://gadm.org/index.html.
[b] https://data.humdata.org/dataset/colombia-administrative-boundaries-levels-0-3.
[c] www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world.
[d] www.protectedplanet.net/en/thematic-areas/wdpa?tab=WDPA.

benchmarked using a before-after-control-intervention (BACI) approach modeled on Bos *et al* [4]. Methodological details are found in table 2. First, change in forest cover loss in the intervention area is assessed before and after ($I_{A\text{-}B}$) the project start year at the most detailed available spatial scale. Second, the equivalent forest loss trend in a subnational or national 'comparison' area ($C_{A\text{-}B}$) is subtracted from $I_{A\text{-}B}$. This approach results in a BACI score. A negative score is desirable as it indicates a stronger decline (or slower rise) in deforestation in the project area compared to the comparison area. Unlike control areas used in REDD+ impact evaluation to identify the causal effect of REDD+ [25], the comparison areas used to calculate these BACI scores do not allow us to separate the project's effect from the effects of site selection and other confounders.

2.2. Issues in integrating REDD+ projects into national scale carbon accounting

We analyze two issues: (a) alignment to national accounting methods (i.e. 'nesting'), and (b) managing and monitoring emissions displaced outside project boundaries ('leakage') [14, 27–29]. Both analyses use data from the above snapshot [18].

2.2.1. Alignment in carbon accounting methods at project and national levels

Aligning carbon accounting at project and national levels avoids double crediting and ensures appropriate attribution when ERs are claimed, sold, or traded [30]. The opposite, divergence, happens when different carbon accounting methods are applied, resulting in different baselines and ER projections, which could present difficulties for aligning project and national level accounting systems. For example, projects that predate national FREL could not have based their methods on the country's carbon accounting methods as described in its FREL. We analyze the extent of divergence using two methods. First, we collect the validation year of Verra-certified projects as a proxy for the year when the project's carbon accounting was conducted. This is compared with the year of the first national FREL submission to the UNFCCC. Second, we compare project vs country carbon accounting parameters relevant for nesting (i.e. emission sources, carbon pools, non-CO_2 gases, and reference period[7]), based on country FREL submission to the UNFCCC [31–33][8].

2.2.2. Project leakage accounting

A REDD+ project may cause leakage (i.e. emissions displaced outside project boundaries) and must monitor and manage this risk. While both projects and national REDD+ may cause leakage across national borders, most of the concern around leakages focuses on appropriately attributing all changes in emissions that occur within the country. A nested national accounting system needs to attribute leakage to projects that cause them. Such systems are better supported if projects are monitoring and accounting their leakage. We summarize leakage accounting and monitoring approaches from REDD+ in Colombia, Indonesia and Peru and describe the extent to which they are practiced by projects.

3. Results

3.1. How much can REDD+ projects contribute to effective forest carbon ERs globally?

3.1.1. Global snapshot of REDD+ projects

Between 2018 and 2020, there were 377 ongoing REDD+ projects across 56 countries, covering 53 million ha (mha) (figure 1) compared to 2.08 billion ha of forest cover in those countries [34]. Project sizes range from a small 4 ha AR project to a 10 mha AD project (SI appendix, figures S1–S3 available online at stacks.iop.org/ERL/17/044038/mmedia). Almost all areas (95% or 50.4 mha) are in AD projects. The majority (75%) of the area in REDD+ projects is in Brazil, Colombia, Indonesia, Myanmar and Kenya. The top five countries in terms of number of projects are Colombia (n = 44), Brazil (n = 43), China (n = 39), India (n = 25) and Kenya (n = 22), closely followed by Indonesia and Peru (n = 21). AR projects predominate in China (72%), India (88%) and Kenya (55%), while AD projects predominate in Colombia (59%), Brazil (67%), Indonesia (86%) and Peru (57%). There are more yet smaller AR projects than AD projects (AR: n = 198, average 0.001 ± 0.003 mha; AD: n = 144, average 0.350 ± 1.027 mha)[9].

Since 2014, project types and geographies have diversified to include more AR projects, mirrored by the geographical shift away from countries with more AD projects (e.g. Indonesia, Peru and DRC) to AR-heavy countries (e.g. China, India and Kenya). There are more projects now (377 in 2020 vs 345 in 2014), but less total area under projects (53 mha in 2020 vs 72 mha in 2014). Countries with the largest number of projects in 2014 were Brazil (n = 41), Indonesia (n = 29), Peru (n = 21), Colombia (n = 20) and the Democratic Republic of Congo (n = 18). By 2020, Indonesia, Peru and DRC fell off the top five and were replaced by China, India and Kenya.

Certification under voluntary carbon market standards continues to be important for REDD+ projects [17] (figures 2 and 3). Two-thirds of REDD+ project areas are in projects that are currently certified or have sought certification. Most certified areas (92%) are in AD projects (figure 2). More than one-third (35%, 18.5 mha) of area and 268 (71%) ongoing projects are certified as of September 2020, most of them by Verra; the remaining are certified under Plan Vivo, Gold Standard, CDM, Brazil Mata Viva, and Natural Forest Standard. Half of the project areas that are not certified have sought certification. The proportion of area under certification varies greatly across regions. Africa has the highest proportions with 75% of projects and 80% of project area certified, practically all (99%) under Verra (figure 3).

A long time gap between project start and sales of carbon credits reduces the financial return. We find no clear trend in diminishing time gaps and differences across certification standards. We analyze 161 projects certified through Verra (n = 145) and Plan Vivo (n = 16) that started between 2007 and 2017. By September 2020, 96 projects had their first sale, after facing an average time gap of 4.68 ± 2.4 years. All Plan Vivo projects had their first sale after 3.25 ± 2.2 years. In contrast, 80 (55%) Verra projects had their first sale after 4.96 ± 2.3 years[10]. The difference in time gap across AD and AR projects is smaller than the difference across certification standards (AD = 4.4 ± 2.0 years, n = 59; AR = 4.8 ± 2.9 years, n = 33). Among projects that started between 2007 and 2013, the proportion that sold credits within 7 years varied between 40% and 80% (figure 4).

The number of new projects peaked in 2011 (45 projects), 4 years after the COP13 of UNFCCC, when REDD+ was accepted as a global climate change mitigation strategy. The number steadily declined to five new projects in 2019 (figure 5). The same

[7] Emission sources, carbon pools and GHG gasses were accounting parameters identified in Pearson et al (2016, p 10) [39]. We also analyze reference level period, as this is essential for calculating baseline emissions in most accepted methods.

[8] Colombia has since updated its FREL in February 2021, but we use the 2016 version because our REDD+ database was last updated in 2020.

[9] Uncertainty in averages are expressed in n = sample size, average value ± one standard deviation.

[10] Comparison between Plan Vivo and Verra (VCS/CBS) carbon accounting standards is described in [40].

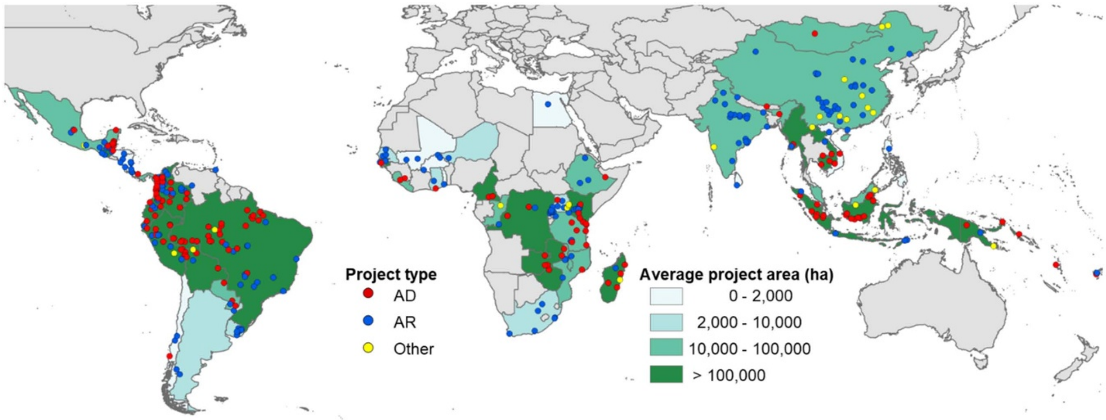

Figure 1. Geographic distribution of REDD+ projects REDD+ project types: avoided deforestation and degradation and forest conservation (AD), afforestation/reforestation/revegetation (AR) and other goals (other).
Note: Dots show the approximate location of 377 projects.

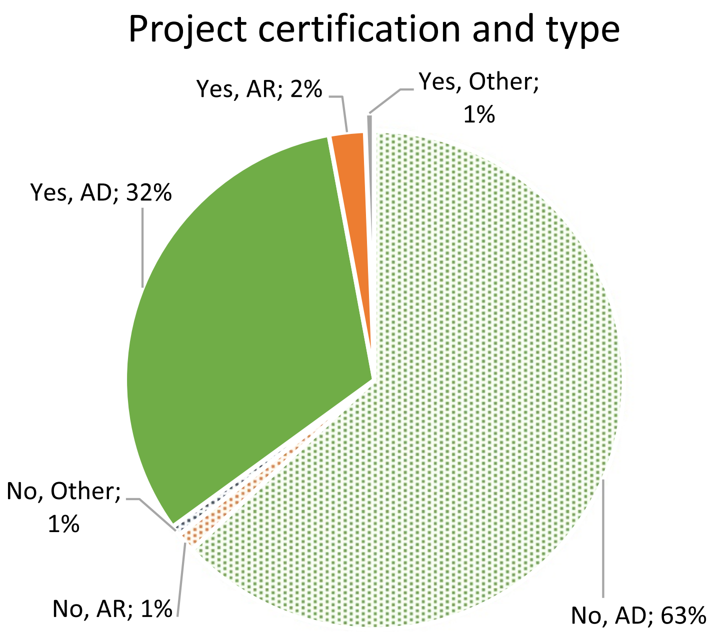

Figure 2. Project area by dominant project type (AR/AD/other) and certification status (yes = certified; no = uncertified).
Note: The figure excludes 12 projects without area data.

pattern is found across regions. REDD+ projects are now planned for slightly longer time horizons (35.7 ± 18.75 years, $n = 340$) compared to the 30 year average found in 2014. AR projects are planned to last 10 years more than AD projects (AR: 40.84 ± 21.11 years, $n = 191$; AD: 29.5 ± 11.38 years, $n = 127$) (figure 6).

Estimated ERs (EERs) from REDD+ projects vary by country, project type and certification status (SI appendix table S1). Averaging across areas[11], REDD+ projects estimated that they can annually reduce 3.67 t of CO_2 equivalent per ha (tCO2e yr ha^{-1}). In 12 countries with at least five certified projects with complete data, averages range by country from 1.6 tCO2e yr ha^{-1} (Tanzania) to 21.4 tCO_2e yr ha^{-1} (Nicaragua) (SI appendix figure S4). Averaging by project results in higher estimates (19.29 ± 63.59 tCO_2e yr ha^{-1}), reflecting the effect of small yet numerous AR projects with higher ER yr ha^{-1}.

Location suitability for AD projects: most (75%) are located in fully suitable or partially suitable areas with high opportunity (i.e. forest biomass present) and/or high historic pressure on forests (i.e. forest emissions) (clusters A–C in figure 7).

A quarter (25%) of the AD projects is located in less suitable locations, with low historic forest

[11] EER/ha refers to total EER divided by total area for 322 projects with both data = 137 362 447 tCO_2e yr^{-1} ÷ 37 477 361 ha. To be distinguished from EER/project ha, which is the average of EER/project area across projects.

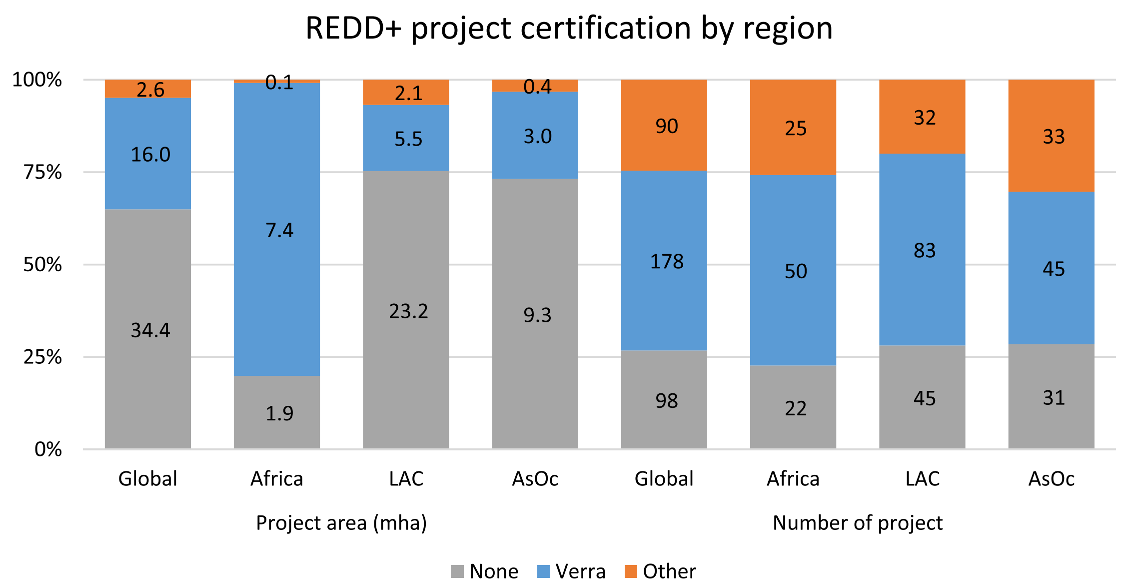

Figure 3. Proportion of area in REDD+ project by certification status.
Note: Data taken August–December 2020; figure excludes 11 projects without area size data. LAC: Latin America and the Caribbean, AsOc: Asia and Oceania.

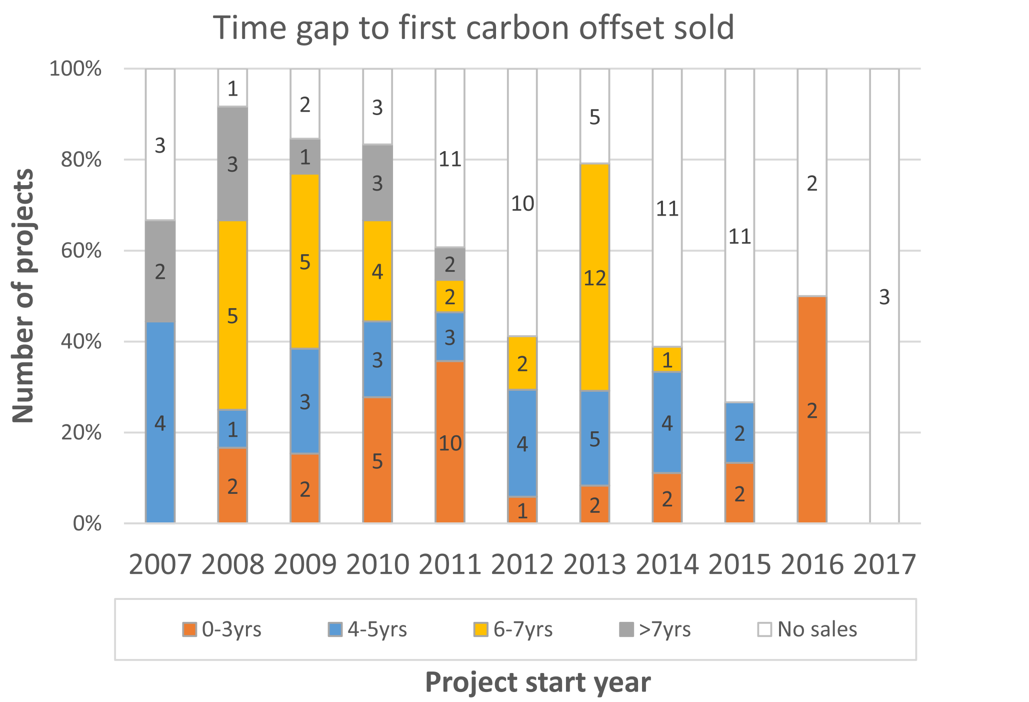

Figure 4. Number of years between project start and first carbon offsets sold.
Note: Figure includes 161 Verra and Plan Vivo-certified projects that started between 2007 and 2017. Data as of September 2020.

emissions and low forest biomass that would perhaps be more suitable for AR projects (cluster D). Most AD projects in LAC (76%), and to a lesser extent in AsOc (66%) are located in the most suitable location clusters A and B while most African projects (68%) are located in the least suitable location cluster D. Location suitability of AR projects based on restoration potential is higher for projects in LAC compared to projects in AsOc and Africa (figure 8). Comparing restoration potential in project locations to continental restoration 'hotspots', i.e. locations with values above the 75% quartile, only 25% of LAC

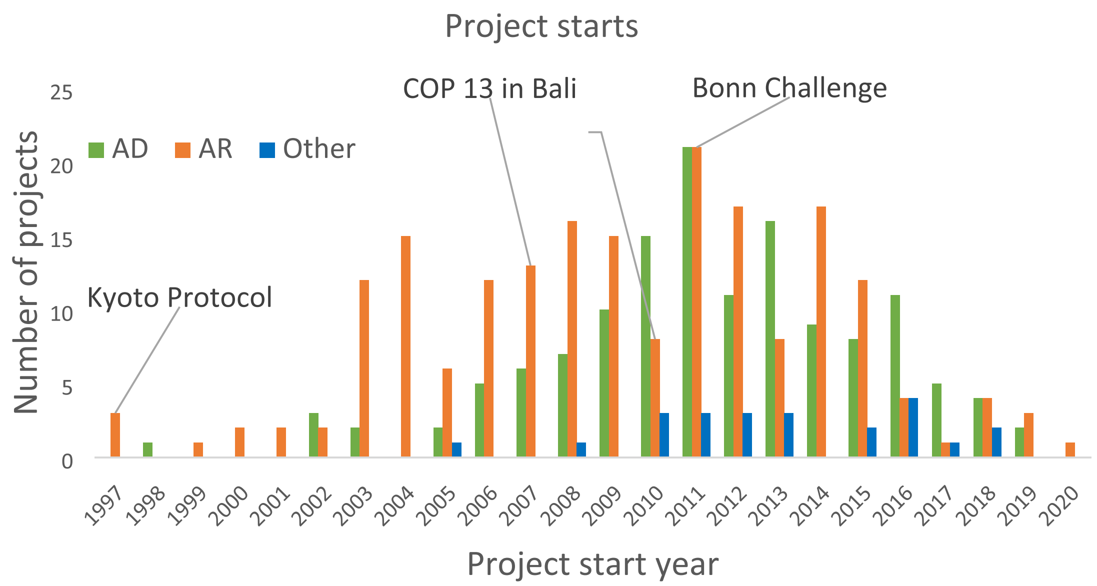

Figure 5. Number of projects by start year and project type.
Note: 14 projects that started prior to 1997 are not displayed in this figure.

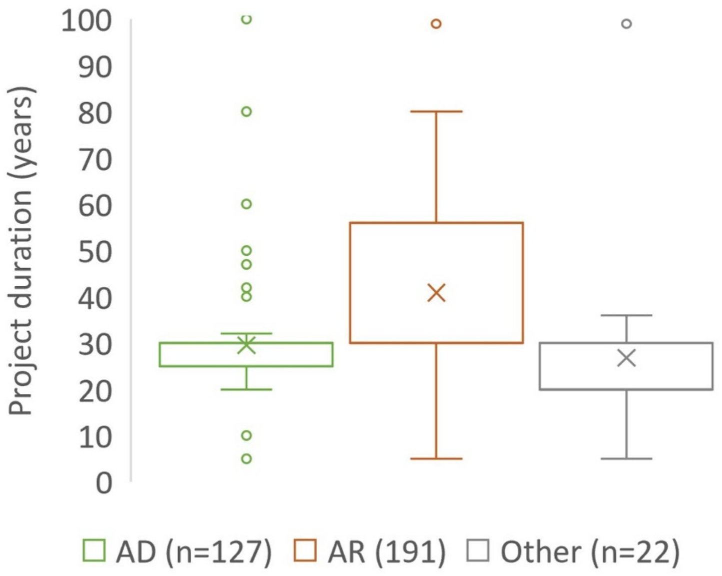

Figure 6. Distribution of planned project duration (year) by type of project.

projects are located in restoration hotspots. These numbers are even lower for AsOc (21%) and Africa (18%).

3.1.2. Benchmarking exercises to gauge project contributions to global and national ERs

REDD+ projects are still far below their mitigation potential due to their small spatial coverage compared to the total forest area under pressure. The total expected ERs from 325 REDD+ projects with available data is 141 $MtCO_2e\ yr^{-1}$. This is about 2.3% of the 6081 $MtCO_2e\ yr^{-1}$ that tropical and subtropical forests can potentially contribute towards limiting global warming to <2 °C (table 3) [23].

Hypothetically, if AD projects are scaled up to cover all forest areas in REDD+ countries, these projects would be expected to avoid emissions nearly equivalent (91%) to total emissions from forest loss (orange highlight, table 4). Expected ER per ha of project area is less than the average emissions per ha of forest loss (i.e. ratio <1 in table 4). In Africa and in most countries with at least four AD projects, the ratio is greater than one, suggesting that projects have been located where there are more forest carbon emissions than average (green highlight, table 4).

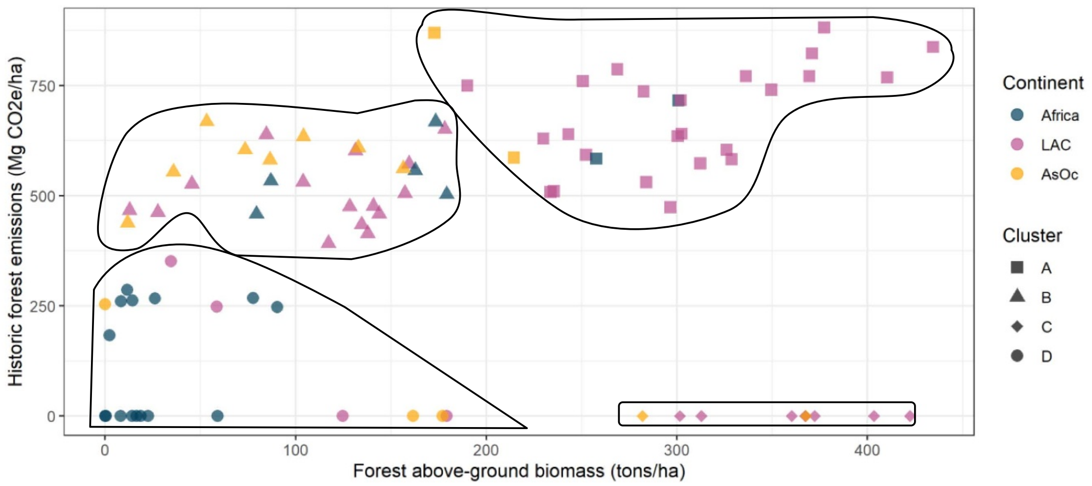

Figure 7. AD projects by regional historic forest emissions (2001–2019) and forest above-ground biomass.
Note: Clusters represent 88 AD projects in regions with (A) high emissions-high biomass (32% of AD projects); (B) high emissions-low biomass (32% of AD projects); (C) low emissions-high biomass (11% of AD projects); and (D) low emissions-low biomass (25% of AD projects).

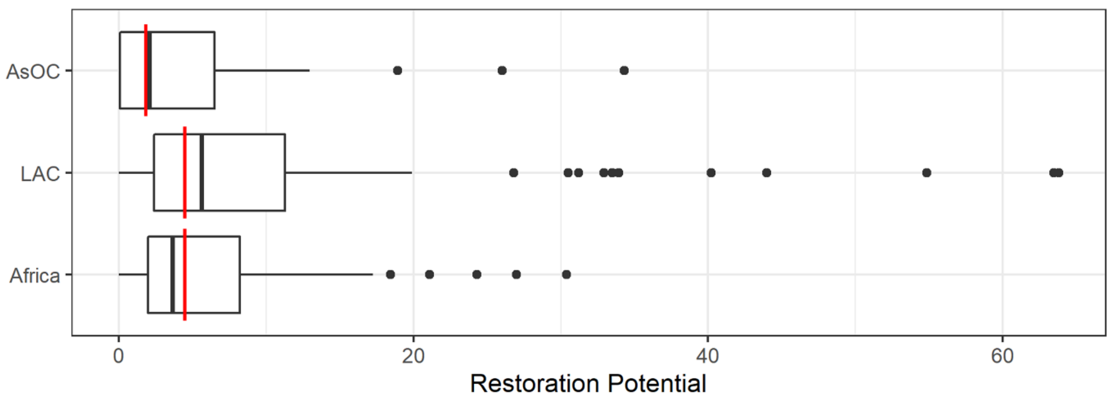

Figure 8. AR projects by restoration potential.
Note: Restoration potential expressed as % of canopy cover that can be restored within the region of project locations. Includes 165 AR projects. Red bars are continental median restoration potential.

Table 3. Benchmarking expected ER with expected forest-based contributions to the <2° climate mitigation target.

REDD+ projects[a]		Benchmark[b]	
REDD+ project type	Expected ER ($MtCO_2e\ yr^{-1}$)	Global mitigation pathway	Contribution to achieve <2 °C target ($MtCO_2e\ yr^{-1}$)
AD	116.0	Avoided forest conversion	2897
AR	14.6	Reforestation—T&S	2407
Other	10.8	Improved plantations—T&S	83
		Natural forest Mgt—T&S	468
		Fire Mgt—Amazon and Global Savannas	116
		Avoided woodfuel harvest	110
Total	141.5	Total	6081

[a] Source: [18], excludes 48 projects without ER and area data; 'other' dominant project type includes IFM with and without logging.
[b] Source: [20], Mgt—management, T&S—tropical and subtropical; natural forest management—native forests with non-intensive management for wood production.

Table 4. Benchmarking rates of avoided emissions from AD projects against rates of emissions from forest loss.

Geography	Obs[a]	Expected ER from AD projects (A/B): Total Est ER ($tCO_2e\ yr^{-1}$)[b] A	Expected ER from AD projects (A/B): Total project area (ha)[b] B	Benchmark: emissions from forest loss in country (C/D): AGB emission (2020 (tCO_2e))[c] C	Benchmark: emissions from forest loss in country (C/D): Forest area (2020 (ha))[b] D	Ratio[d] (A/B):(C/D)
Region						
Africa*	24	27 777 220	7517 503	864 317 718	310 768 600	1.33
AsOc*	22	23 774 113	10 686 662	883 397 385	309 680 480	0.78
LAC*	64	60 451 591	16 828 225	1675 088 318	356 999 650	0.77
All*	110	112 002 924	35 032 390	3422 803 421	977 448 730	0.91
Countries with four or more AD projects						
Kenya	5	4876 391	2626 350	5788 364	3611 090	1.16
Zambia	4	4119 627	1272 803	62 711 917	44 814 030	2.31
Tanzania	4	620 886	407 780	54 963 523	45 745 000	1.27
Indonesia	12	20 105 212	5569 510	378 722 436	92 133 200	0.88
Brazil	18	12 203 835	2665 536	1148 470 444	496 619 600	1.98
Colombia	24	26 142 176	10 601 643	134 043 089	59 141 910	1.09
Peru	11	5257 253	1836 006	132 559 745	72 330 370	1.59

[a] Calculated for countries with at least one ongoing AD project (11 in Africa, eight in AsOc, and nine in LAC). Excludes 41 AD projects with incomplete data.
[b] Source [18].
[c] Source [24].
[d] Ratio = 1 means that ER per ha reported by projects equal the average above ground emissions per ha from forest lost in the country in 2020. Ratio > 1 (green cells) means projects' reduction rates are more than national forest emission rates from above ground biomass loss from forests.

Benchmarking using the BACI method, the intervention areas of most AD and AR projects have lower or equal deforestation trends since project start compared to subnational and national levels (i.e. good or neutral BACI scores, figure 9). A minority (20%) have a greater increase (or smaller decrease) in deforestation rates compared to the subnational or national levels (i.e. poor BACI sores). A higher proportion of AR projects have good BACI scores compared to AD projects. The high proportion of 'neutral' scores among AD projects raises concerns about project additionality, which should be assessed using counterfactual methods (e.g. [14]). The forest cover loss data does not capture subtle changes in tree cover densities and cannot track tree cover loss in non-forest areas. Nevertheless, our findings are consistent with studies that applied counterfactual methods to smaller project samples that find weakly positive impacts of AR and AD projects (e.g. [4, 16]).

3.2. What are the issues in integrating REDD+ projects into national scale accounting?

3.2.1. Alignment in carbon accounting methods at project vs national levels

Focusing on Verra-certified projects, all countries except for Ethiopia, Mozambique and Guinea-Bissau ($n = 35$ of 38) have at least one project that was certified before the submission of their first national FREL (figure 10). Eighty-eight projects were certified before FREL submission, and 47 projects in 11 countries have yet to submit FRELs by June 2021. These 135 projects cover 16 mha and are expected to reduce 45 million $tCO_2e\ yr^{-1}$.

Most projects in Colombia, Indonesia and Peru ($n = 63$ of 86) have at least one parameter that is not aligned with those at the national level often by adopting a wider accounting scope than the country (table 5). Countries are generally more conservative about which carbon pools to include compared to projects (e.g. AGB + BGB in Colombia and Peru, and AGB + peat SOM in Indonesia).

The historical reference periods used by projects are mostly within ($n = 15$ of 86) or overlap ($n = 69$ of 86) those in the country FREL but are rarely (2 of 86) the same (SI appendix figure S5). Indonesia has the largest reference interval (1990–2012) compared to Peru (2001–2014) and Colombia (2000–2012), leading to a higher proportion of projects using reference periods within the national interval (6 of 14 projects).

3.2.2. Project leakage accounting and monitoring

Of 86 REDD+ projects in Colombia, Indonesia and Peru, information on leakage accounting methods is more accessible among projects that are certified ($n = 52$) or have sought certification ($n = 15$). Of the remaining 29 projects that do not provide public information on leakage accounting, most ($n = 17$) were not certified[12]. Of the 68 providing information,

[12] The remaining (one) is certified under Gold Standard. As of June 2021, the project design document was not publicly accessible.

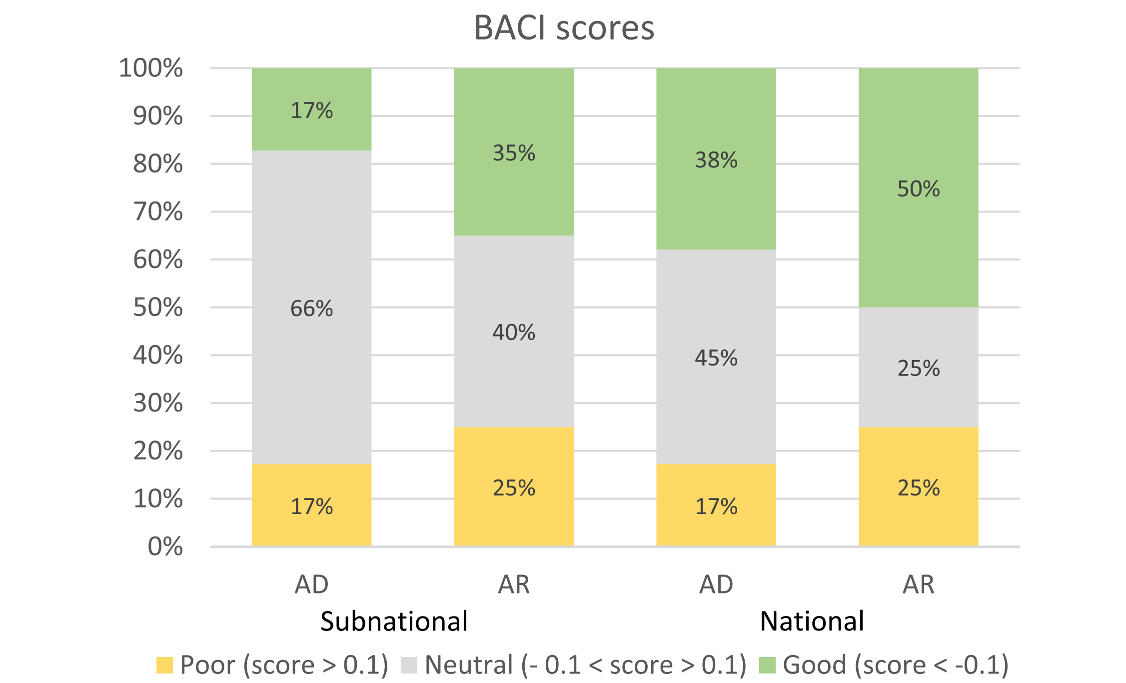

Figure 9. Percentage of AD and AR projects with negative, neutral or positive BACI score relative to subnational (administrative 1 regions) and national level comparison sites.

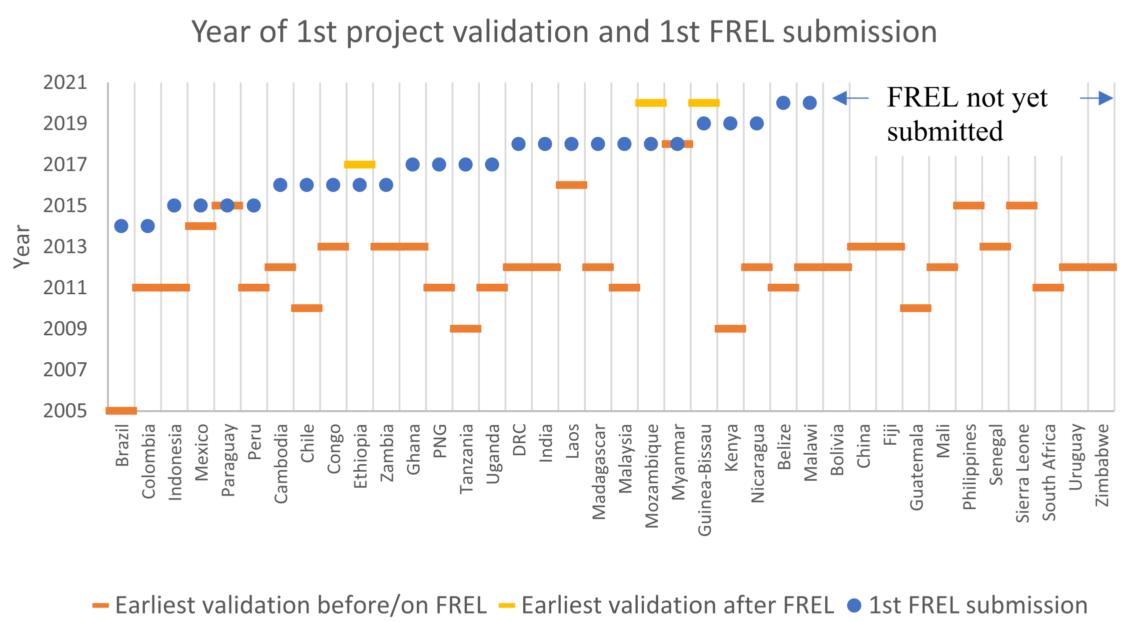

Figure 10. Comparison between year of first project validated by Verra (VCS/CCBS) and year of 1st FREL submission to the UNFCCC.
Note: The figure includes 38 countries with at least one project certified by VCS/CCBS/Verra. Source: year of 1st FREL submission from https://redd.unfccc.int/submissions.html?topic=6, accessed 21 June 2021.

26 projects claim they produce no/insignificant leakage following standard methodologies (table 6). Others (n = 13) go beyond monitoring the standard activity-shifting leakage (i.e. displacement of GHG-emitting activities outside project boundaries by actual agents of deforestation) and monitor other leakage types (ecological leakage, market leakage). Leakage emissions subtracted from the expected ERs estimates were found in 28 projects, equivalent to 1%–33% of their expected project ER.

4. Discussion

4.1. Snapshot of REDD+ projects

Our study shows: (a) the shrinking area in projects and a steady decline of new projects since a peak in

Table 5. Comparison of carbon accounting scope and reference period of REDD+ projects and national FRELs

Colombia, Indonesia and Peru (projects)				
	Carbon accounting scope			
	Same scope	Narrower scope	Wider scope	No data
Emission sources	22	0	43	21
Carbon pools	32	3	35	16
Non-GHG gasses	38	n/a	27	21
⩾1 divergence	10	63		13
	Time period			
	No overlap	Within period	Overlap	No data
Reference period	1	22	43	20

Table 6. Leakage monitoring and accounting among REDD+ projects.

Does the project plan to monitor a leakage belt?				
	Colombia ($N = 44$)	Indonesia ($N = 21$)	Peru ($N = 21$)	Total ($N = 86$)
No data	19	16	6	41
No	14	5	7	26
Yes	11	0	8	19
If yes, key statistics of leakage belt size				
	Size (ha)		% project size	
Min	6253		15%	
Max	2989 186		248%	
Median	25 159		49%	
Does the project plan to account for leakage?				
	Colombia ($N = 44$)	Indonesia ($N = 21$)	Peru ($N = 21$)	Total ($N = 86$)
No data	6	9	3	18
No	17	2	7	26
Yes	21	10	11	42
If yes, what kinds of leakage will be accounted?				
Activity leakage	20	8	11	39
Other leakage (ecological, market, pre-project agricultural activity)	9	3	1	13
If yes, will emissions from leakage be subtracted from ER?				
No data on amount subtracted	6	4	1	11
No leakage emissions subtracted	0	2	1	3
Some leakage emissions subtracted	15	4	9	28
If yes and non-zero leakage emissions subtracted, key statistics:				
	tCO_2e		% exp net ER[a]	
Min	1440		1%	
Max	9941 049		33%	
Median	399 435		6%	

[a] Net ER is the expected ER minus ER that should not be attributed to the project, e.g., leakage, non-permanence, credits registered elsewhere.

2011; (b) the rise of small reforestation (AR) projects notably in China, India and Kenya, promising higher ER per ha compared to AD projects; (c) AD projects comprise 95% of the global area in REDD+ projects; (d) long delay and uncertainty of starting carbon credit sales in voluntary carbon markets; (e) REDD+ projects would need to be upscaled more than 40× to fulfill the potential of tropical forests for contributing towards limiting global warming to <2 °C; (f) scaling up AD projects to all forest areas in countries with REDD+ projects could, theoretically, reduce emissions at a level nearly equal to (91%) that emitted from forest loss in 2020; (g) most AD and AR projects are located in suitable areas, but a small yet substantial proportion are not; and (h) most projects in Peru, Colombia and Indonesia have lower or similar deforestation trends compared to subnational and national levels. Properly selected control areas are needed to estimate project impacts on emissions and assess additionality.

We used benchmarks to gauge the magnitude of ER contributions and location suitability. These are hypothetical exercises as we do not evaluate the robustness of ER contribution nor included geographical heterogeneity at the subnational level. Rather, we show stated contribution to climate change mitigation. This information has largely been unknown in the literature and provides a comparison with independent estimates (e.g. [14], and studies reviewed in [35]). Our location suitability analysis was done at the regional scale as the exact location of project activities was often not available. Projects could have strategically targeted specific locations within the region to maximize their expected ERs. In addition, our analysis does not represent the entire range of carbon and non-carbon contributions of REDD+ projects, nor the social, economic and governance aspects of REDD+ implementation, which are important for local, national and global stakeholders. Non-carbon benefits, such as biodiversity and poverty alleviation potential, has been shown to increase the probability of being selected as a project site [36]. Conversely, non-carbon challenges, such as unclear tenure rights and low law enforcement capacity hinder REDD+ implementation [37].

Our results, although coarse, are sufficient to show that from the perspective of climate mitigation effectiveness, REDD+ projects are currently not at a scale to significantly contribute to the Paris Agreement but could do so in select regions and countries, and spatially targeted areas within those countries. This in itself does not imply that projects should be scaled down (as their contribution is limited) or scaled up (to increase impacts). Our benchmarking exercises do not capture the wide-ranging effects on land, food, labor and carbon credit prices that could result from scaling up REDD+ projects. Rather, it highlights the need to identify locations where REDD+ projects should be scaled up and out, and the overall costs and feasibility of scaling up compared to higher-scale policy reforms.

4.2. REDD+ nesting issues

Most REDD+ projects risk diverging from national carbon accounting methods because they started prior to their country's FREL submission and/or apply a carbon accounting scope that is narrower or wider than the national one. Certification in carbon standards is valid for limited periods (5–10 years), when projects can update carbon accounting parameters in line with national methods. Simultaneously, countries must also conduct intermittent updates as part of the Paris Agreement, potentially leading to perpetual catching up. To break this cycle, multilevel dialogues within and across countries are needed to establish common practices by which countries and projects perform these updates. A substantial proportion of projects accounted for and plan to monitor activities beyond what countries have accounted. Changing the scope of carbon accounting may impose financial cost on projects. Consideration should be given to limiting this cost for early movers who made risky investments in carbon accounting before national rules were established.

Our analysis identifies the technical challenges of nesting, but we are cognizant that financing is also contributing the technical challenge. Aside from the voluntary carbon markets, Colombia, Indonesia and Peru benefit from financing through voluntary carbon markets and various bilateral or multilateral results-based programs (e.g. Forest Carbon Partnership Facility—Carbon Fund, BioCarbon Fund Initiative for Sustainable Forest Landscapes, the REDD+ Results Based Payment program of the Green Climate Fund). Each have their own methods that do not entirely align with the Warsaw Framework (i.e. REDD+ rulebook) that countries use for UNFCCC reporting and accounting [38]. These methodological differences might jeopardize the integrity of any integrated carbon accounting system, whether at the national or global levels.

Valuable information available from REDD+ projects is difficult to include in national reporting due the fragmented nature of project reporting. Some projects are well-documented because they participate in one of a growing number of carbon certification standards. There are other projects outside of the carbon certification ecosystem, whose basic characteristics—let alone ERs—are difficult to discern. This underscores the importance of a global database on REDD+ projects such as the one used and refined in this paper.

5. Conclusion

Our analysis provides a picture of REDD+ projects at a crossroads. After the boom of REDD+ projects following COP13 in 2007, and the slump a decade later, the coming few years will likely determine the position of REDD+ projects in helping countries reduce emissions. REDD+ projects need to find its role in a world seeking large-scale solutions. We find a steady decline in the number of new REDD+ projects since a peak in 2011 and long gaps between project start and sales in voluntary carbon markets. REDD+ projects would need to be upscaled >40× to fulfill the potential contribution of tropical and subtropical forests towards limiting global warming to <2 °C. Our analysis in Colombia, Peru and Indonesia finds divergence between carbon accounting parameters used at the national and project scale. As part of the Paris Agreement, countries should improve their accounting practices to eliminate double counting across accounting scales. This implies harmonizing carbon accounting methods with REDD+ projects and avoiding a perpetual game of catch-up between different scales.

With a downward trajectory of new project starts, it is easy to let REDD+ projects die a quiet death and replace them with an entirely jurisdictional focus. But what is at stake? REDD+ projects bring the local, bottom-up, non-state element that complements rather than substitutes top-down jurisdictional programs, necessary for forming a multi-level coalition of actors needed to bring about change. Indeed, our study shows that REDD+ projects are first movers: they act early, take financial risks, follow standards, and access financing from the private sector in the voluntary carbon market. The argument for REDD+ projects lies not only in the total ERs that they can achieve, but also in their role in diversifying participation in REDD+ and providing non-carbon benefits to local communities, potentially leading to broader support for future climate action. More financing options for project establishment need to be made available given the long gap between project start and first carbon credit transactions, enabling REDD+ projects to start and continue to reduce emissions. Further research on multi-level information flows and stakeholder communication in the context of nested carbon accounting is needed.

Analysis of the challenges and opportunities for nesting REDD+ projects suggest that requiring full methodological alignment across levels and actors is challenging, but possible. Financing is an important part of the problem and solution. Divergence, rather than alignment, will remain if REDD+ financing mechanisms for projects and jurisdictions continue to use different carbon accounting methods. Finalization of Article 6 of the Paris Agreement that provides access to wider financing options may further bolster ongoing efforts to integrate voluntary carbon market projects into jurisdictional REDD+ programs.

Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: https://doi.org/10.17528/CIFOR/DATA.00272.

Attribution

Writing—original draft (S S A, V D S, A E D, E O S); Design of methodology (S S A, V D S, A E D, E O S, A A); Management and coordination responsibility for the research activity planning and execution (S S A, A E D); Writing—review and editing (S S A, V D S, A E D, A A, M K, V S); Data collection and curation (S S A, V S, M K); Data analysis and interpretation (S A, V D S).

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