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Adaptive approaches to REDD+ are needed for countries with high forest cover and low deforestation rates

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Abstract

Reducing emissions from deforestation and forest degradation (REDD+) aims to maintain forest carbon stocks above benchmark reference levels through financial compensation. However, countries with high forest cover and low deforestation (HFLD) are unlikely to be compensated fairly if REDD+ initiatives fail to conserve existing forests and to incentivize low deforestation rates. Here we analyze the submissions of forest reference levels (FRLs) of five HFLD countries [Democratic Republic of the Congo (DRC), Republic of the Congo (Congo), Guyana, Papua New Guinea, Suriname] to the REDD+ platform of the United Nations Framework Convention on Climate Change. We assessed if the FRLs are likely to yield compensation payments that maintain carbon stocks above the business-as-usual scenario and compared the FRLs with quantitative emission data. Our results show that only Guyana submitted an FRL that yielded sufficient monetary incentives for low deforestation rates. Compensation payments will likely be insufficient in Suriname, Papua New Guinea, and the Congo. The FRL of the DRC would generate the highest compensation payment (on average US$ 1.3 billion annually). Overall, our results suggest that payments from REDD+ will fail to provide adequate incentives for most HFLD countries. We suggest that the FRL should allow for post hoc adaptation to changes in the drivers of deforestation. This implies that REDD+ schemes need sufficient flexibility to reflect changes in the opportunity costs of alternative land uses, which is particularly acute for HFLD countries where pressure on forests can accumulate rapidly. More adaptive REDD+ likely better rewards HFLD countries in ways that preserve their valuable forest ecosystems.

1. Introduction

Tropical deforestation and forest degradation cause major carbon dioxide emissions and are responsible for substantial losses of biodiversity (Pan *et al* 2011, Gibson *et al* 2013). Tree cover loss in the tropics accounts for 8% of global carbon emissions, and lower deforestation rates are necessary to achieve the emission-reduction goals set forth in the Paris Agreement (Gibbs *et al* 2018). One promising avenue to do so is REDD+, which stands for reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

REDD+ is a compensation mechanism under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC). REDD+ aims to incentivize land uses to increase the amount of carbon stored in the landscape as compared with a

business-as-usual (BAU) pathway. The BAU is the so-called forest reference level (FRL), that sets the benchmark against which future emissions from deforestation and forest degradation or the increase of forest carbon stocks are compared (Herold *et al* 2012, FAO 2020a). FRLs aim to ensure efficient allocation of performance-based incentive payments in REDD+ schemes and, as such, should follow recommended guidelines as proposed in the reports of the UNFCCC (https://unfccc.int/topics/land-use/resources/redd-documents). However, future emissions are highly uncertain because business is often not usual. Future land use can change in unexpected ways, driven by often sudden and fundamental, yet unexpected changes in boundary conditions, such as the effects of the Russian invasion in Ukraine on global food systems have once again shown. Overall, FRLs aim to strike a balance between providing sufficient incentives to reduce emissions from land use and avoiding the risk of paying for emission reductions that would have occurred anyway (Herold *et al* 2012, Mertz *et al* 2018). As a result, existing FRLs are based on political compromises resulting from negotiation.

Countries that submit applications to the UNFCCC are required to propose an FRL that forms their baseline against which future emission reductions are rewarded with carbon credits. Countries participating in REDD+ have an incentive to aim for a high FRL (i.e. high forest-related emissions in the BAU without REDD+ intervention) to ensure that reductions in emissions below the baseline are easy to achieve and that high emission reductions will generate high payments (Rifai *et al* 2015, Mertz *et al* 2018). Overestimation of FRLs could in turn undermine the credibility of REDD+ as a cost-efficient results-based payment scheme to mitigate emissions from land use (Dezécache *et al* 2018, Neeff 2021). Overestimation is less likely to lead to additional mitigation of forest emissions. Underestimation, in contrast, would result in incentive payments below the opportunity costs of land use, and thus fail to yield the envisaged emission reductions.

The uncertainties inherent in emission reduction estimations are important to consider. Buyers of carbon credits generated by REDD+ can benefit from high emission reductions per dollar invested (i.e. are interested in a low FRL) to maximize the returns on their investments. The agreed-upon FRL will define the efforts that are necessary to secure payments from REDD+ schemes; these payments serve to incentivize forest land uses that reduce emissions below the BAU (Angelsen 2017). Setting an appropriate FRL therefore is a cornerstone of REDD+ and subject to an intensive negotiation process between suppliers and providers of the results-based finance through REDD+.

One key challenge for successful REDD+ implementation is to address the underlying drivers of deforestation, and how the drivers affect the proximate causes of deforestation and forest degradation (Hosonuma *et al* 2012, Curtis *et al* 2018). The underlying drivers are conditioned by distinct site conditions and local processes. In smallholder systems, particularly if these serve subsistence purposes, the interplay of population growth and technological change will govern the demand for land and therefore the expansion of land use. In contrast, future deforestation rates in commodity-driven deforestation frontiers mainly respond to changes in global commodity prices, technology, infrastructure, and tenure relations (Meyfroidt *et al* 2014). REDD+ schemes need to account for these drivers and thus factor in site- and actor-specific conditions that prevail in the target locations. In addition, REDD+ must anticipate and address future drivers and causes of deforestation and forest degradation to convince the suppliers of REDD+ finance of the permanency of the emission reductions.

REDD+ interventions to reduce emissions from land-use change in countries with high forest cover and low deforestation (HFLD) can be particularly valuable because HFLD countries harbor high carbon stocks and largely undisturbed forests. HFLD countries tend to be in the pre-transition phase on the forest transition curve (Mather 1992), which suggests that economic development will shift the pre-transition countries into an early-transition phase with accelerating deforestation rates (Mertz *et al* 2012, Angelsen and Rudel 2013). If the forest transition curve approximates future deforestation rates in the HFLD countries, then linear extrapolation of historical deforestation rates, as often done in setting FRLs, will underestimate future deforestation (Angelsen 2017). Unfortunately, specific guidelines by the UNFCCC that support HFLD countries in setting their FRLs are lacking to date. The FRLs in the HFLD countries often relied on anecdotal knowledge, data from often inadequate national monitoring systems, sometimes augmented with global monitoring data. Formulating an FRL is the result of political negotiations and, as such, can be distorted by power imbalances, such as those between international technical experts and national policy makers.

Many arguments speak in favor of shifting more attention to the HFLD countries, because these countries are a symbol of REDD+'s ability to mitigate carbon emission and fostering conservation (Dezécache *et al* 2018), as they harbor vast tracts of primary forests that store large amounts of carbon per unit area in their biomass, have high levels of endemic biodiversity, and provide important watershed protection (Guadalupe *et al* 2018). Historically, HFLD countries have low deforestation rates. Many of the HFLD countries are under severe risk of international leakage related to the displacement of forest loss from other countries, which take advantage of the vast 'unused' land resources in the HFLD countries,

while protecting their domestic forests (Meyfroidt and Lambin 2009, Dezécache *et al* 2017). REDD+ implementation needs to account for HFLD countries' special circumstances to become an effective mechanism.

Researchers have recommended an adjusted approach for HFLD countries because the linear extrapolation of historic deforestation rates for setting the FRL is inappropriate (Parker *et al* 2009, Herold *et al* 2012). This approach considers national circumstances by anticipating rising opportunity costs of land use in response to future economic development, population pressure, infrastructure construction, and higher commodity prices. One option to adjust the FRL is to use global average deforestation as the benchmark against which to compare national historic deforestation, and provide payments under the premise of staying below this benchmark (Strassburg *et al* 2009). Another suggestion has been to use regression or simulation models that HFLD countries' positions along the forest transition curve (Köthke *et al* 2014). However, the ability to forecast future emissions is questionable, as land-use changes can accelerate rapidly due to unforeseen events caused by anthropogenic or natural disturbances, or through a gradual accumulation of drivers beyond a tipping point (Müller *et al* 2014, Doupe 2015, Fletcher *et al* 2016).

Here, we focus on how FRLs have been set in HFLD countries' submissions to the UNFCCC. This is important given the paucity of research on establishing FRLs for the distinct HFLD circumstances, to outline pathways for how REDD+ can achieve forest protection for HFLD cases, and because of HFLD countries' importance for the global climate system and for tropical habitats. Our overall aim is to suggest approaches for establishing FRLs that are consistent, plausible, and efficient in reducing future forest carbon loss in the special circumstances of the HFLD countries. We are not aware of a peer-reviewed scientific comparison of FRLs of the HFLD countries and hence our work fills a notable research gap. We selected five HFLD countries on three continents (Suriname, Guyana, Papua New Guinea, Republic of the Congo, and Democratic Republic of the Congo). All countries are in the tropics, and all handed in their official submissions to the UNFCCC between 2015 and 2018. We qualitatively compared the FRLs from these submissions with regard to their efficiency in providing adequate incentives through REDD+ credits toward lowering emissions. We also used global data of gross forest emissions to quantify the potential results-based compensation payments. Specifically, we address the following research questions:

(a) Which methods were used to estimate FRLs in the selected HFLD submissions?
(b) Can adequate incentives for forest conservation be generated for each HFLD country?
(c) Which drivers of forest loss have been considered in the FRL, and how likely are these drivers to determine future emission pathways?

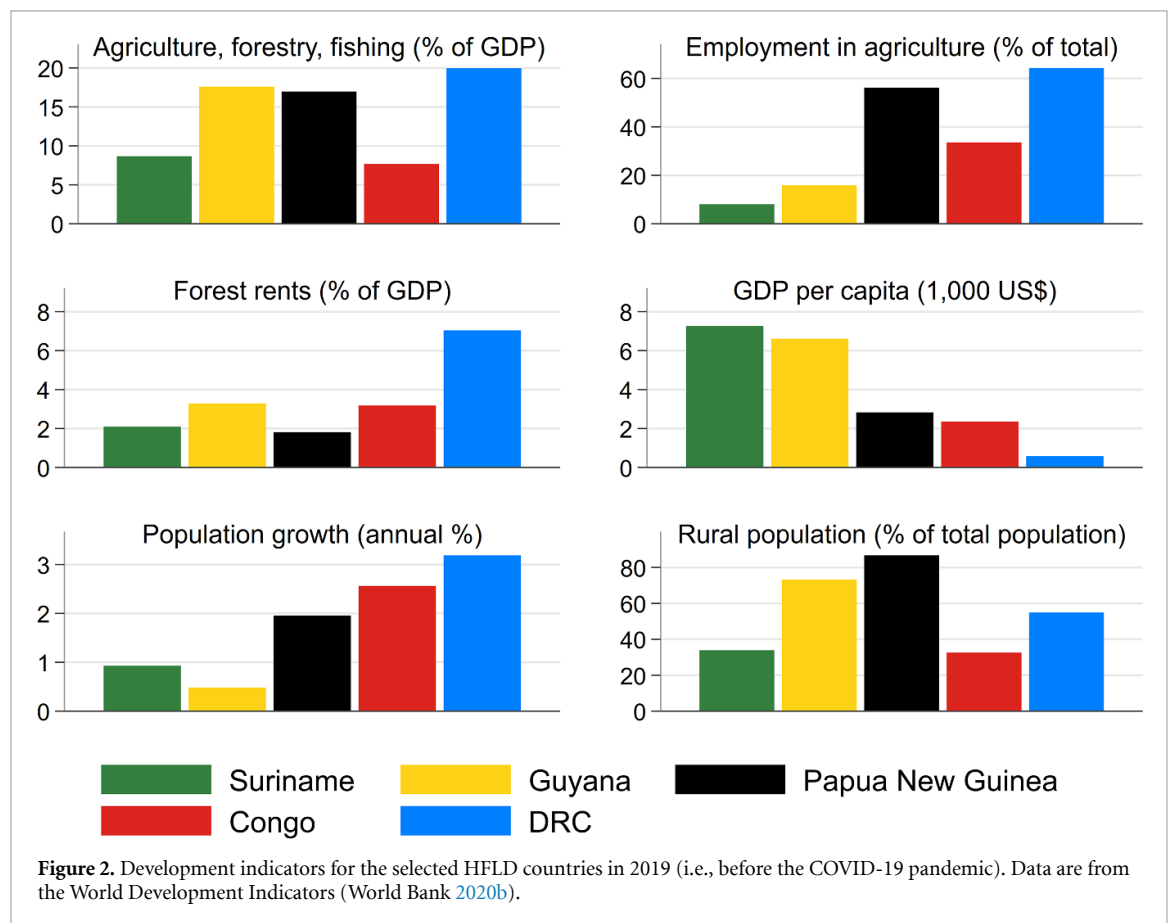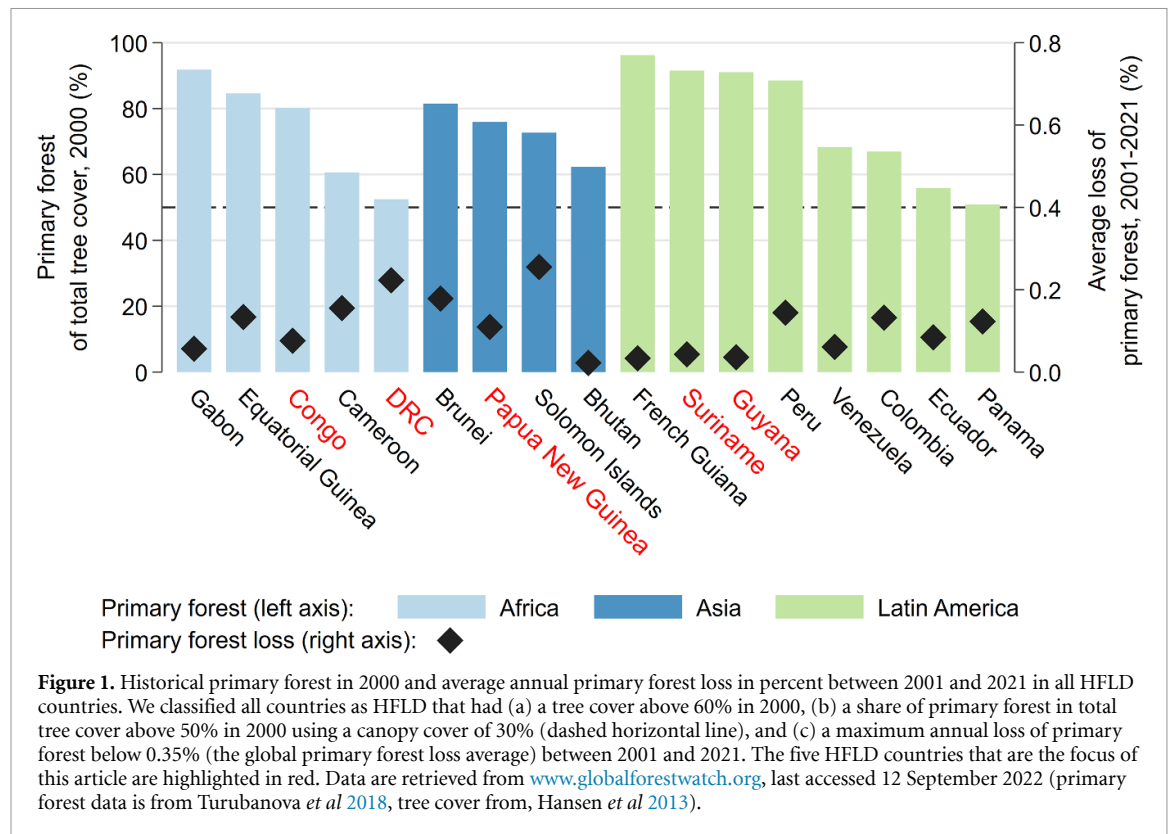## 2. Materials and methods

2.1. Selected HFLD countries

HFLD countries have been characterized by a forest cover of more than 50% and annual deforestation rates that are substantially below the global average (da Fonseca *et al* 2007, Hosonuma *et al* 2012). We refine existing definitions and categorize HFLD countries as those with (a) a tree cover above 60%, with (b) at least a 50% share of primary forest in total tree cover in 2000 with at least 30% canopy cover, and (c) an annual rate of primary forest loss below the global average of 0.35% between 2001 and 2021. For calculating the global average rate, we only considered countries with at least five estimates of primary forest loss between 2001 and 2021. In total, 17 countries fall under this HFLD definition (figure 1). These countries have a combined tree cover of 615 Mha and a primary forest cover of 420 Mha (data obtained from www.globalforestwatch.org last accessed 12 September 2022); primary forest cover stems from Turubanova *et al* (2018), who distinguish it from other cover types, such as secondary regrowth and plantations, that were mapped by Hansen *et al* (2013).

Two of the five selected HFLD countries are in the northern Amazon basin (Guyana, Suriname), two in the Congo basin (Republic of the Congo, the Congo hereafter, and the Democratic Republic of the Congo, the DRC hereafter), and Papua New Guinea in the southwestern Pacific. Tree cover in 2000 exceeded 77% in all five countries with a share of primary forest between 52% and 92% and the annual primary forest loss rate between 2001 and 2021 ranged from 0.04% in Guyana and Suriname to 0.22% in the DRC (www.globalforestwatch.org, last accessed 12 September 2022).

The DRC is a low-income country, whereas the other four are middle-income countries (World Bank 2020a). Gross domestic product (GDP) per capita and year ranges from US$ 581 in the DRC to US$ 7211 in Suriname in 2019 (figure 2). One-third of the population lives in rural areas in the Congo and Suriname, 55% in the DRC, 73% in Guyana, and 87% in Papua New Guinea. Population growth is highest in the two African countries and lowest in the two South American countries. The rents derived from forests constitute 7% of GDP in the DRC but less than half of that in all other countries (figure 2).

2.2. Study design

We used the submissions of the five selected HFLD countries (Government of the Cooperative Republic Guyana 2015, Government of Papua New Guinea 2017, La République du Congo 2017, Government

Figure 1. Historical primary forest in 2000 and average annual primary forest loss in percent between 2001 and 2021 in all HFLD countries. We classified all countries as HFLD that had (a) a tree cover above 60% in 2000, (b) a share of primary forest in total tree cover above 50% in 2000 using a canopy cover of 30% (dashed horizontal line), and (c) a maximum annual loss of primary forest below 0.35% (the global primary forest loss average) between 2001 and 2021. The five HFLD countries that are the focus of this article are highlighted in red. Data are retrieved from www.globalforestwatch.org, last accessed 12 September 2022 (primary forest data is from Turubanova *et al* 2018, tree cover from, Hansen *et al* 2013).

Figure 2. Development indicators for the selected HFLD countries in 2019 (i.e., before the COVID-19 pandemic). Data are from the World Development Indicators (World Bank 2020b).

of Suriname 2018, La République démocratique du Congo 2018), which are publicly available at the REDD+ web platform of the UNFCCC (https://redd.unfccc.int, last accessed 10 October 2020). We scanned all submissions and created categories with information that can be compared among the five countries, including their FRL definition, REDD+ activities, and the drivers of estimated forest loss.

We harmonized the terminology from the submission texts to ensure consistency and comparability. Although Suriname, Guyana, the Congo, and the DRC submitted a forest reference emission level (FREL), we used the more comprehensive term FRL, which also accounts for potential emission reductions from the enhancement of carbon stocks (the UNFCCC does not distinguish between FRL and FREL FAO 2020a). Papua New Guinea submitted an FRL, which includes an estimation of emissions by sources and removals by sinks. Papua New Guinea set the removals to zero in their FRL due to missing uncertainty estimates for the historical reference period. Hence the remaining REDD+ activities in the FRLs of all five countries are deforestation and forest degradation.

To provide a quantitative and comparable counterfactual baseline of emission estimates, we used tree cover data from 2000 (Hansen *et al* 2013). The tree cover data are the first consistent, annually available, and high-resolution global data of tree cover loss. The algorithm detects stand-replacing disturbances, which are not necessarily equal to deforestation. For example, the harvesting of tree plantations and shifting cultivation practices represent tree cover loss despite subsequent regrowth or replanting (Tropek *et al* 2014). Forest degradation is also not captured, although degradation amounts to at least 20% of the emissions in the FRLs of Papua New Guinea, Suriname, and Guyana (FAO 2020a). We refer to tree cover and tree cover loss when the underlying data are from the global tree cover data from Hansen *et al* (2013); however, we use deforestation and forest loss when we discuss the carbon dynamics utilizing activity data in the REDD+ context.

We used the data of annual gross forest emissions for multiple carbon pools (described in Harris *et al* 2021 and obtained from www.globalforestwatch.org, last accessed 15 May 2022). The dataset combines the tree cover loss data from Hansen *et al* (2013) with the modeling results on annual per-pixel forest biomass summed by country. We contrast the estimates of forest emissions with the FRLs to assess how close the proposed emissions in the country submissions are to the global estimate. We approximate the payments gap between the FRL and the reported annual emissions per country by multiplying the difference between the proposed FRL and the annual gross forest emissions with a carbon price of US$ 5/ton CO_2 (used by the UNFCCC's Green Climate Fund).

3. Results

3.1. Establishment of FRLs

All five countries proposed FRLs that are higher than their average historical emissions (figure 3). Guyana proposed an FRL that is almost 400% higher than the country's historical emissions between 2001 and 2012. The DRC suggested an FRL that is 132% above

historical emissions during the reference period; Suriname's FRL is 140% higher; and the FRLs of the Congo and Papua New Guinea are equivalent to an increase in future deforestation by 85% and 48% compared to the baseline year 2000. The historical and proposed emissions of the DRC are larger than those of the other selected countries because the DRC had higher historic deforestation rates and proposed higher future emissions due to the expected rapid population growth. The large difference in Guyana's historical emissions and FRL compared to Suriname, Papua New Guinea, and the Congo is due to the estimation of Guyana's FRL in relation to a substantially higher global emission rate.
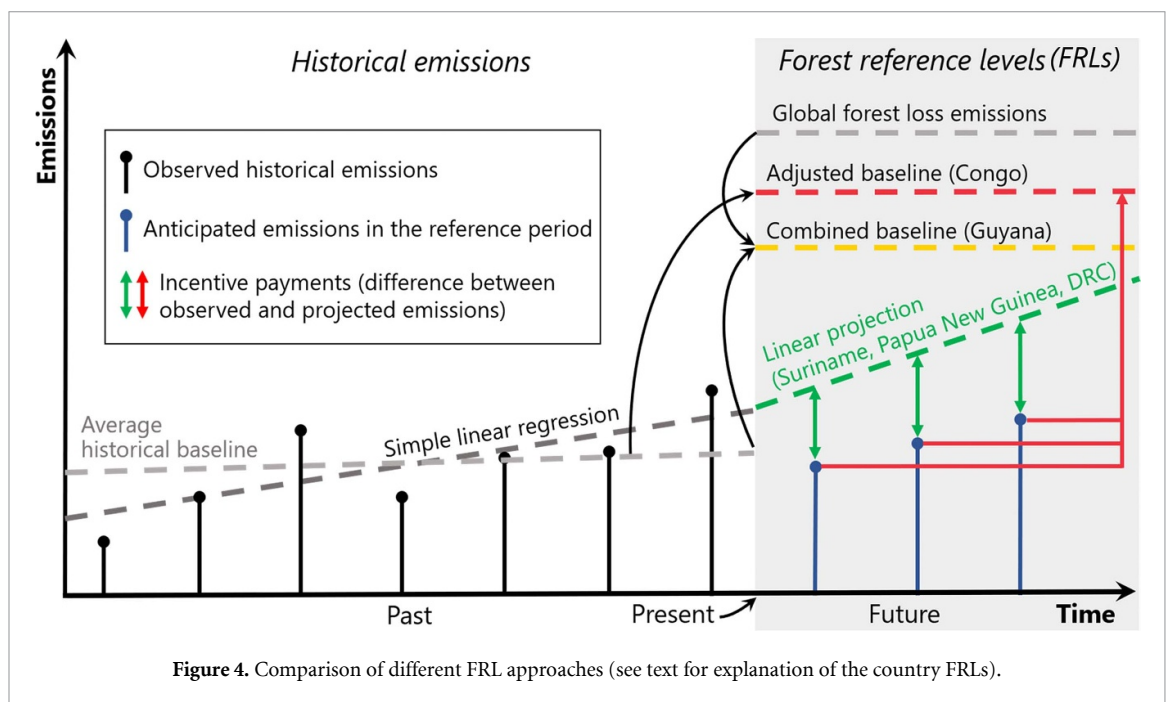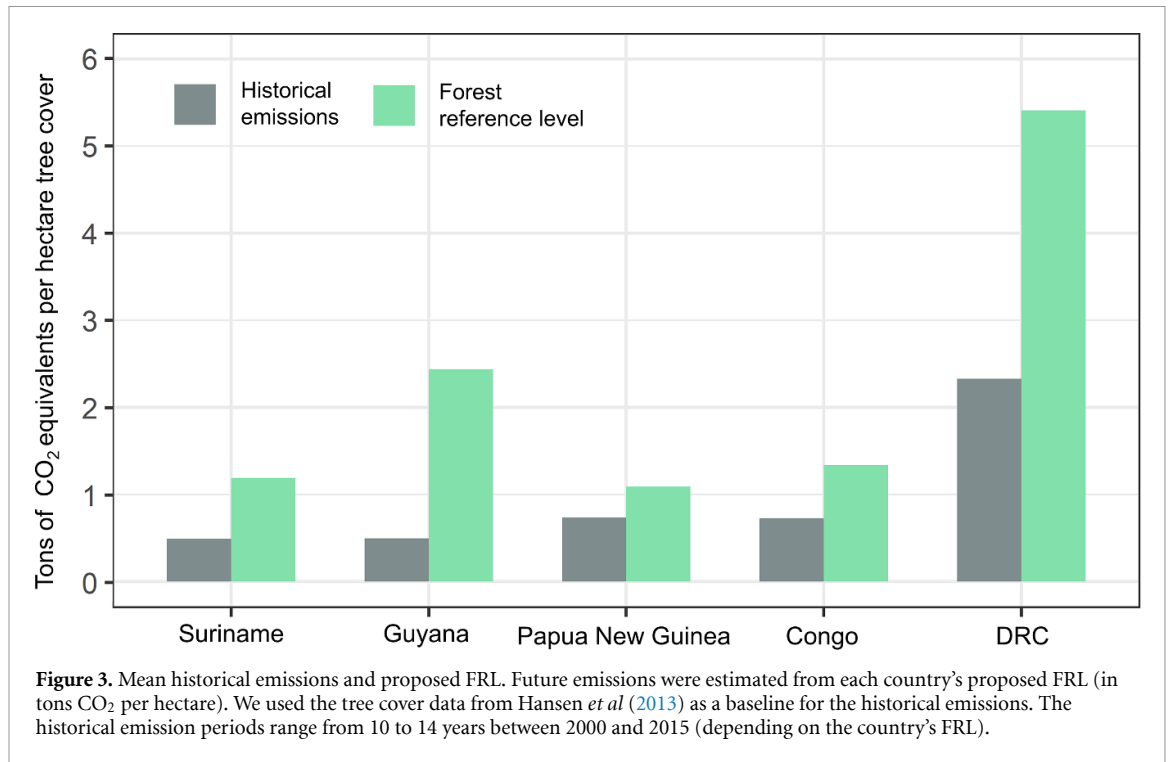
The five submissions differ in their projection method, the REDD+ activities that are accounted for, and whether and how drivers of projected forest loss are included (supplementary table 1). Suriname, Papua New Guinea, and the DRC used a linear projection based on a regression of the average annual historical emissions. Guyana embarked on a more complex approach for FRL construction and used the global average emissions as a benchmark against which the development of national deforestation is accounted for (supplementary table 1, figure 4).

Guyana and the Congo adjusted their FRL upward to account for national circumstances (figure 4). Guyana, with financial and technical support from the government of Norway, adjusted its FRL to a level four times higher than its historical emission rates. In addition, Guyana established a crediting baseline with a sliding scale based on a bilateral agreement with Norway during the program from 2010 to 2015, which incentivizes maintaining deforestation rates below a threshold while it penalizes higher deforestation rates with reduced payments. The Congo used an adjusted approach with expected emissions from forest loss that are 85% higher than historical emissions due to anticipated economic development. Suriname refined its baseline with preliminary results from a scenario model based on a national development plan and stakeholder involvement, but the results were deemed to inaccurate to be utilized for an adjusted FRL. Suriname, Papua New Guinea, and the DRC used linear regressions to project historical emissions into the future and abstained, in contrast to the other selected countries, from claiming an upward adjustment for national circumstances (figure 4).

3.2. Potential incentive payments

Our comparison of the country FRLs with independent emission estimates suggests that Papua New Guinea and the Congo set their FRLs lower than the gross forest emissions (figure 5). Therefore, incentives from results-based payments are likely not sufficient to incentivize the envisaged emission reductions. Suriname, the DRC, and Guyana potentially receive adequate monetary incentives from results-based

Figure 3. Mean historical emissions and proposed FRL. Future emissions were estimated from each country's proposed FRL (in tons CO_2 per hectare). We used the tree cover data from Hansen *et al* (2013) as a baseline for the historical emissions. The historical emission periods range from 10 to 14 years between 2000 and 2015 (depending on the country's FRL).

Figure 4. Comparison of different FRL approaches (see text for explanation of the country FRLs).

payments because gross emissions are below the proposed FRL.

In monetary terms, the average annual REDD+ incentives for Suriname would sum up to US$ 14 million (the difference between the proposed FRL and the gross forest emissions multiplied with US$ 5/ton CO_2) (figure 5). This amounts to an income of annually US$ 1 per hectare total tree cover from avoided forest loss between 2016 and 2020. Guyana's FRL is well above the estimated gross forest emissions and

would generate US$ 181 million on average annually, the highest income among the five countries with US$ 9.5 per hectare total tree cover of avoided forest loss. The DRC could generate the largest absolute results-based emission reductions with up to 400 million tons CO_2 in 2015, which could provide US$ 2 billion from the REDD+ credit buyers. In relation to the DRC's total tree cover, REDD+ incentives of US$ 7 could be generated per hectare annually for the reference period (figure 5).
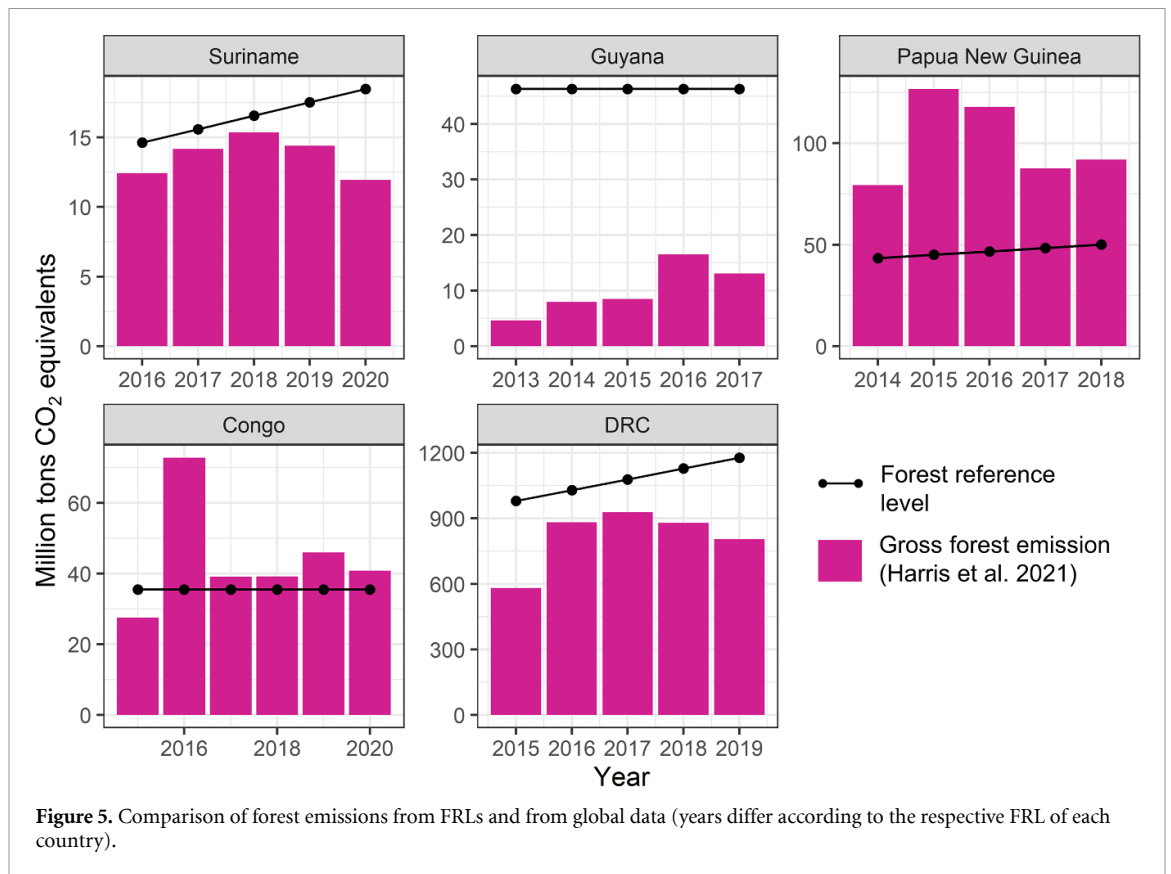
Figure 5. Comparison of forest emissions from FRLs and from global data (years differ according to the respective FRL of each country).

3.3. Reflection on drivers

In all submissions, the drivers for the respective REDD+ activities are mentioned and considered in the FRL calculations (supplementary table 1). However, the submissions differ widely in the way and diligence with which future development of the drivers and their impact on forest cover have been assessed. Some countries considered a narrow set of drivers and did not account for the impact of these drivers on future emissions in a transparent, quantitative manner. For example, Suriname and Guyana projected that gold mining will contribute about 50% of their future emissions from deforestation, without providing much rationale for this estimate other than referring to increasing gold prices and to background studies. Both African countries listed agricultural expansion and urbanization as the most influential drivers for future deforestation, followed by mining. Papua New Guinea proposed in its submission that emissions from forest degradation due to logging for timber extraction will constitute the major share of future degradation emissions, whereas agricultural expansion is expected to cause 99% of the emissions related to deforestation. The other four countries also expected logging to be the biggest driver for forest degradation.

4. Discussion

We examined the official FRL submissions of five countries with high forest cover but low deforestation to the REDD+ platform of the UNFCCC. Forest loss in all five HFLD countries has accelerated since 2000, and the pressure on forested areas are likely to rise further (FAO 2020b). All countries account for the rising pressure for their forest resources with FRLs that anticipate accelerating emissions from forested areas. However, all submissions differ in the amounts of these increases and how they were calculated.

Results-based payments will likely fail to generate sufficient conservation payments for the Congo, Papua New Guinea, and Suriname. Guyana and the DRC have the largest gap between FRL and the gross forest emissions, and can thus potentially receive the highest results-based payments. The Congo and Papua New Guinea are unlikely to receive sufficient incentive payments because their gross forest emissions were higher than their proposed FRL. Suriname's FRL performed slightly above the gross forest emissions, suggesting that results-based payments can incentivize lower forest emissions. In addition, Papua New Guinea reported emission reductions in 2014 and 2015 but did not claim the results-based

payments; instead, it opted to improve REDD+ monitoring, reporting, and verification system (Government of Papua New Guinea 2018). We conclude that results-based compensation payments with a carbon price of US$ 5/ton CO_2 are likely too low to compensate for the opportunity costs of land use. Besides, it is important to point out that several countries, such as Papua New Guinea, have set FRLs below those that would have been expected in a profit-maximizing strategy. We are unable to scrutinize the underlying reasoning of such behavior, which would require in-depth interviews with the officials of the respective countries. We, however, based our analysis on the formal submissions to the UNFCCC. None of the countries proposed a simple historical average, which would be prejudicial for HFLD countries (Angelsen *et al* 2011). The linear projection of historic deforestation emissions, which Suriname, the DRC, and Papua New Guinea used, are likely too conservative because these countries have low historical deforestation rates, which result in low expected future deforestation in the FRL. Using historical averages will therefore likely lead to underpayment and insufficient monetary incentives (Angelsen 2008). The linear projections used by Suriname and Papua New Guinea are prone to fail in providing sufficient incentive payments for reducing forest emissions. The DRC, in contrast, may generate the highest potential emission reductions of all five countries with 1.3 billion tons CO_2 for the FRL period, according to our estimate. The high historical values of forest emissions at the end of the reference period suggest the DRC can propose a higher FRL than the other HFLD countries. We point out the need for clarity in the terminology of what constitutes an upward adjustment and when the FRL rests on linear regression.

Upward adjustment of future carbon emissions due to land-use change has been deemed appropriate for HFLD countries (Walker *et al* 2013). However, our analysis shows that three of the five FRLs failed to account for such upward adjustment due to a paucity of data and a lack of capacity to pursue credible forecasting. In Guyana, the bilateral agreement with Norway led to a crediting baseline that is linked to low future emissions, which suggests a fair chance that future forest loss may be reduced through the REDD+ payments (Roopsind *et al* 2019). When REDD+ reference levels are overestimated the value of REDD+ is at risk, which in turn can undermine the integrity of the entire mechanism (Dyer and Counsell 2010, Angelsen 2017). For example, the DRC declared that its high FRL anticipates higher future forest loss caused by expected population growth and rising demands on charcoal. However, setting such a high FRL could be interpreted as 'environmental blackmailing' as countries anticipate excessive deforestation, such as what Guyana had in its original offer to Norway (Karsenty and Ongolo 2012). Overall, this corroborates how delicate the bargaining process of

defining the FRL is, particularly for HFLD countries, because small changes in the projection may produce fundamentally different trajectories with substantial effects on incentive payments.

All five countries had difficulties accounting for the drivers of future deforestation and forest degradation, and all embarked on ad hoc estimates to anticipate the effects of these drivers. Assessing the drivers' effects on the opportunity costs of the land uses that compete with forests, as well as how these opportunity costs may change with time, is hotly debated. Key drivers of land-use change, such as agricultural commodity prices, technological change, and shifts in consumer preferences, often develop in unexpected ways, as witnessed by the food price spikes in 2022. As a result, anticipating future land-use change is extremely challenging because land use can respond to many existing or to newly emerging drivers in unexpected ways (Müller *et al* 2014, Ramankutty and Coomes 2016). Knowledge about potential trajectories of land use, both based on theoretical advancements and on growing evidence from case studies, is accumulating rapidly (Meyfroidt *et al* 2018). Yet, remaining bias toward some standard narratives of deforestation in national institutions and policies impedes the ability to tackle major drivers of forest loss and to find long-term sustainable forest conservation practices (Wong *et al* 2019, Skutsch and Turnhout 2020). For example, smallholder deforestation continues to be blamed as an important culprit despite patchy empirical evidence (Branch *et al* 2022, Wong *et al* 2022) and the fact that shifting cultivation is mainly causing forest degradation rather than deforestation (Mertz *et al* 2012). Besides, conclusions on the drivers of deforestation frequently rely purely on remotely sensed land-cover changes without supporting local evidence on underlying processes of land use change (as, e.g. in Curtis *et al* 2018). However, field-level insights on local land-use changes can reveal fundamentally different underlying drivers and proximate causes of deforestation (Dressler *et al* 2017, Ravikumar *et al* 2017).

In general, nuanced insights on the drivers of forest loss enhance the ability of setting realistic FRLs. For example, forecasts of forest cover trajectories based on the forest transition theory and under consideration of the development of salient and known drivers can help in generating more nuanced FRLs (Köthke *et al* 2014). This is especially true for HFLD countries, which are in the early stages along the forest transition curve. Moreover, the ample co-benefits from REDD+ in HFLD countries, such as for habitat preservation, can be used to uplift the FRL estimations toward providing incentives that internalize the environmental costs of forest loss (Dezécache *et al* 2018).

Given the lack of data on opportunity costs, let alone the difficulty of projecting those into the future, we abstained from a comparison of the

future development of opportunity costs across the HFLD countries. However, it is of utmost importance that REDD+ schemes contain mechanisms that buffer against unexpected future developments of the drivers and, hence, for changes in the opportunity costs that could jeopardize the successes of REDD+. A focus on specific national circumstances in setting the FRL, additional research on the trajectories of future land-use changes, robust monitoring systems, and embracing the uncertainty inherent in any forecasting exercise are critical to improve the consideration of drivers in FRL definitions.

The success of REDD+ is strongly related to whether the pressure on forested areas stems from changes in global or in domestic demand for forest-consuming commodities. We suggest that changes in the opportunity costs related to international commodity supply chains can be addressed via flexible REDD+ payments that adjust to these changes, which could benefit Guyana, Suriname, and Papua New Guinea. One way to do so could be with markup payments proportional to the changes in the commodity prices where those have been shown to be key drivers for deforestation (Dezécache *et al* 2017). When domestic pressure on forests is high, other measures, such as support for sustainable development of smallholder agriculture, incentives for sustainable forestry, and improved control mechanisms to reduce illegal logging, could be more promising (Galford *et al* 2015, Pretty *et al* 2018); these measures arguably provide more efficient incentives in the Congo and the DRC.

5. Conclusion

Successful initiatives to prevent rising deforestation rates in the HFLD countries are urgently needed, and REDD+ may serve as one such initiative. However, REDD+ is prone to fail in HFLD cases due to the disadvantages of the HFLD countries in carving out efficient FRLs. We presented the first systematic analysis of how HFLD countries constructed their FRLs by analyzing the official submissions of five HFLD countries to the UNFCCC. The results of our analysis suggest that higher flexibility in considering the specific national circumstances of the HFLD cases will improve REDD+ outcomes. We particularly highlighted that adjustments to the future emissions trajectories, including allowances for rising opportunity costs of forest conservation due to external changes in commodity prices, will improve the likelihood of cost-efficient and effective outcomes. When the causes of deforestation are endogenous, such as through rising rural population pressure, other means are more likely to succeed in forest resources, such as local development initiatives. It remains important to carefully weigh the opportunities and challenges inherent in REDD+ because the protection of tropical forest resources in the HFLD countries can generate substantial emission reductions and provide much-needed co-benefits for biodiversity and people.

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