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National REDD+ outcompetes gold and logging: the potential of cleaning profit chains.

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Abstract

While the potential contribution of a nationally implemented program for Reducing Emissions from Deforestation and Forest Degradation (REDD+) to developing countries' budgets remains as yet obscure, two general concerns are that REDD+ will i) incentivize land grabbing and ii) remain financially uncompetitive against current commercial forest uses. However, based on data from Guyana's, United Nations-approved, Forest Reference Emission Level (FREL) submission and national documents, we found that i) national REDD+ appears not to place value on forest, but financial penalties on forest damage, and ii) would be competitive when viewed from the perspective of the owner of the natural resources (national society), even against high value commodities such as gold and timber (the country's main emission drivers), and at an intermediate US$5 carbon price. Hidden by the latter is a very skewed sharing of net revenue between the state and private sector supply chains (~1:99). Weak law enforcement, common across the tropics, enhances skewed sharing, and linked political leverage likely undermines any plans that would interfere with private income streams, including rural development, land tenure and conservation plans.

We suggest that government or electorate pressure towards more equitable revenue sharing, i.e. 'cleaning profit chains', would both be justified and worthwhile, and unlikely to produce job losses. Investing this homegrown finance in better management and law enforcement of finite natural resources (under REDD+, including forests) could return significant REDD+ income while mitigating climate change and aiding rights of forest-dependent livelihoods. Along with cleaning supply chains and moving commodities out of natural forest areas, assessing and cleaning private profit chains may more generally be a promising approach for REDD+ and climate mitigation goals, along with its many associated social and environmental co-benefits.

Keywords
REDD+ financial competitiveness; forest commodities; private-state revenue sharing; land grabbing; equity; political interventions.

1. Introduction

The 2015 Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) in Paris saw a renewed global-level acceptance of the need to act on human-driven climate change. Nearly 200 member countries of the UNFCCC pledged to collectively reduce carbon dioxide emissions to a level sufficient to restrict temperature increases to less than 2° Celsius above pre-industrial levels (UNFCCC 2015a). The agreement included placing additional emphasis on the reduction of emissions from deforestation and forest degradation and enhancing carbon stocks (REDD+) programs as a mitigation option (*Ibid.* Article 5). REDD+ is designed to provide developing countries with a financial incentive to reduce carbon emissions from tropical forest uses, which currently produce about 10% of global anthropogenic carbon emissions (4.8 of 49 $GtCO_2.yr^{-1}$, Pan et al. 2011, IPCC 2014), equating to 9 billion barrels of crude oil per year (Carnegie Endowment for International Peace, 2015). The Paris Agreement, coupled with the urgency for global carbon dioxide (CO_2) reductions (Carbon Tracker Initiative et al. 2017, CPLC 2017), have provided additional confidence to recipient and donor countries to continue their investment in national REDD+ readiness and implementation activities. The number of countries that submitted a forest reference emission level (FREL) proposal to the United Nations (UN), for example, has risen from six by the end of 2015 to 25 by the last quarter of 2017, from a total 62 participating countries (FCPF 2017, UNFCCC 2017).

As a program for reducing CO_2 emissions, REDD+ is geared towards rewarding climate change mitigation activities at the national level (Angelsen 2009, Eliasch 2008, Meridian Institute 2011,

UNFCCC 2016, 2017), with many REDD+ projects implemented as demonstration and learning experiences (Angelsen 2016). At the implementation stage, REDD+ payment levels to countries will be based on the demonstrated annual performance against the country-specific crediting baseline or reference level, which is derived from a country's historical emission levels (Meridian Institute 2011, Angelsen 2016). REDD+ requires that countries develop the capacity to i) accurately calculate historical CO_2 emissions from deforestation and degradation activities (to calculate the reference emission level, i.e. the hitherto normal annual forest emissions), ii) provide accurate data on carbon density variation in forests across the country (total standing carbon stock), and iii) monitor and annually report, at a national level and in an externally verifiable manner, forest emissions from both deforestation and degradation to calculate performance against the baseline (Angelsen 2009, May-Tobin 2011, Meridian Institute 2011, Strassburg et al. 2009, UNFCCC 2017). By the end of 2015, most countries did not yet have the capacity to provide the required information (UNFCCC 2017), and experiences accounted for in the literature on the program's performance have therefore been based on projects and subnational levels initiatives (Sills et al. 2014, Fischer et al. 2015). Consequently, potential REDD+ earnings at national levels remain obscure.

Meanwhile, beyond meeting the stringent requirements to report on the performance of their carbon stocks, a challenge faced by both donor agencies and target countries is the concern that revenues to be earned from REDD+ may be unable to compete with those derived from highly profitable deforestation-based industries (Butler et al. 2009, Pacheco et al. 2012, Turnhout et al. 2016, Wong et al. 2016). In fact, Boucher (2015) noted that at the global level REDD+ funding is, and will likely remain, insignificant (5.4%) compared to the financial benefits attributed to the four major industries driving tropical deforestation (beef, soybeans, palm oil, and wood products). Boucher examined the global carbon market dynamics and suggested that the available funding

for the main industries dwarfs what is available for the carbon market. While such estimates are important and point to the challenges countries face in deciding to invest in REDD+, they raise questions as to whether developing countries should use their forests for revenue accruing to the private sector or on revenue accruing to the country. In this paper we take the latter perspective by examining how state revenue streams from REDD+ in the South-American country of Guyana will compare with those from gold mining and logging, the country's main drivers of forest emissions.

In late 2015, Guyana was the first country to provide comprehensive reference level details in its Forest Reference Emission Level (FREL) submission to the UNFCCC, i.e. nationwide and including forest degradation emissions (Government of Guyana [GoG] 2015a, UNFCCC 2017). The submission has been approved by the UN's technical assessment as appropriate as an interim approach (UNFCCC 2015b), and includes justification of the proposed steps to calculate annual performance payments. This allows for the calculation of financial outcomes regarding REDD+ under different emissions scenarios, and provides the first opportunity to estimate the financial contribution of REDD+ at the country level, and how this compares with state returns of commercial forest uses. It also permits an assessment of another major REDD+ concern, increased land grabbing. Land grabbing by elites or a 'resource rush' is expected "when REDD+ gives value to a new commodity (forest carbon)" (e.g., Sunderlin et al. 2014, Larson et al. 2013, Loft et al. 2015). This could put pressure on many forest-dependent people with no legal tenure but only customary rights to the forests they use.

Specifically, in this paper we:

a) Examine how Guyana's UN-approved national REDD+ program functions, consider how national level differs from sub-national level REDD+ projects, and contemplate whether the program incentivizes forest grabbing.

b) Assess the financial significance of REDD+ for the national budget, and compare it to state revenue from gold mining and logging before and after including REDD+ opportunity costs,
c) Assess cumulative private and state net revenue shares per hectare, based on legally declared amounts and on estimates of under declaration and inefficient gold recovery, and
d) Discuss the potential for improving the owner's share of natural resources, or 'cleaning profit chains'.

Our paper contributes to global REDD+ discussions by i) showing for the first time how REDD+ implemented nationally would financially perform from the perspective of the owner instead of the commercial users of the natural resources, and ii) by drawing attention to very skewed private-state revenue sharing of natural resources and the probable consequences of this relationship.

2. Materials and methods

2.1 Guyana's national REDD+ program

Background information on Guyana and its development of REDD+ is presented in Supplementary Note S1. Guyana's FREL submission to the UN states that its mean annual CO_2 emission rate during its reporting period (2001—2012) was 0.049% (GoG 2015a). This is the portion of its total forest carbon stock, in CO_2 equivalents, emitted per year through deforestation and forest degradation, and is one of the lowest emission rates in the world. The main drivers of forest emissions were the mining and logging sectors, contributing 49% and 42% respectively to the annual total of 9.4 million metric tons of CO_2. The remaining emissions came from agriculture (7%) and infrastructure development (2%) (GoG 2015a). Emissions from deforestation are monitored by countrywide high-resolution satellite imagery (RapidEye, 5m resolution), reported annually, and externally verified (Guyana Forestry Commission [GFC] and

INDUFOR 2015). Emissions from forest degradation related to logging are currently calculated from annual timber harvest records, combined with emission factors from a detailed field study in Guyana on extracted volume, incidental damage and residues, and infrastructural damage (Pearson et al. 2014).

In its technically approved FREL submission (UNFCCC 2015b) Guyana adopted the Combined Incentive approach of Strassburg et al. (2009) to develop a payment model. It is an appropriate model that –crucially– provides financial incentives to *all* tropical forest nations to join REDD+ (Strassburg et al. 2009, May-Tobin 2011) by rewarding both reductions in emissions and maintenance of forest cover. The model seeks to avoid international leakage of emissions by providing an incentive for High Forest Low Deforestation (HFLD) countries such as Guyana to join REDD+ programs to maintain low emissions levels. If payments were only based on emission reductions, developing countries with historically low forest emission rates would have little incentive to join REDD+. Instead, they could be persuaded to accept offers from forest based industries that come under pressure in other REDD+ countries to operate in their forest, resulting in not a reduction but a relocation of emissions in the first country (Strassburg et al. 2009). Based on Guyana's submission (GoG 2015a), potential REDD+ revenue can be calculated as:

$$\text{Annual Revenue in Year}_x = (\text{Reference Emission Level} - \text{Actual Emission Level in Yr}_x) \times \text{Guyana's forest } CO_2 \text{ stock in Yr}_{x-1} \times \text{Carbon price} \quad (1)$$

Guyana's approved reference emission level is 0.242%, which is the 'combined average' of the mean pan-tropical historical emission rate (0.435%, adapted from Baccini et al. 2012) and Guyana's mean historical emission rate of 0.049% (GoG 2015a, UNFCCC 2015b). The reference

level marks the tons of CO_2 against which Guyana's annual emissions are compared (0.242% of its forest CO_2 stock, i.e. C-stock times the C-to-CO_2 conversion factor (44/12)). The difference is the rate at which Guyana has avoided emissions, which is multiplied by the carbon price to arrive at the amount of revenue earned that year (Equation 1; see Supplementary Note S2 for more details).

Guyana reported that its forests contain an average 284 metric tons of carbon (tC, or megagram, Mg) per hectare (aboveground and belowground living biomass pools, range 239 – 331, GoG 2015a) and uses the interim carbon price set by Brazil's Amazon Fund (US$5 per tCO_2, Joint Concept Note 2015) to determine revenue; we adopt the same price in our analysis, and briefly evaluate effects of higher carbon prices which are deemed urgently needed by prominent sources to meet the Paris temperature target (CPLC 2017, Carbon Tracker et al. 2017).

2.2 Variables and data

The aim of the paper is to assess national REDD+'s financial 'competitiveness' against commercial land uses from the perspective of the owner of the natural resources, hence decision maker, which in this case is the state. We used the variable 'state revenue' (further explained in Sections 2.3 – 2.5) for three reasons. First, state revenue much more reflects real state earnings of a sector than for example 'GDP' (gross domestic product) or 'foreign exchange earnings'. Particularly in the case of gold, GDP is a distortive indicator. Since Guyana charges the private miner 7% of the gold value (5% royalty + 2% tax), this implies 93% of gold's GDP value is bought with state funds. Second, state revenue allows for the comparison of state returns from different types of commercial forest use (CFU), and against forgone revenue from these sectors' forest emissions under a national REDD+ program. Third, state revenue can be compared with

185 estimates of private returns to provide insights into how overall revenue of the resource is shared
186 between the owner and exploiter.
187 State revenue does not comprise all benefits of CFU sectors, as a country's economy additionally
188 benefits from employment and financial inputs from salaries and investments, and from materials
189 and services the sector uses (see further section 2.4). Although there is logic in the reverse as
190 well; there would be no gold and wood production and resulting private profit without the
191 country's workers and services. In addition, governments can forego significant revenue from
192 sector concessions and subsidies (e.g., Ministry of Natural Resources and Environment 2015,
193 McFarland et al. 2015, UN-REDD 2016), and it has control- and administrative costs of the
194 sector. These aspects are however not relevant for our paper which focuses on net profits of CFU,
195 which arise as a product of the labor, i.e. after production and labor costs are paid.
196 We estimated cumulative net profits of all links in the commodity supply chain (i.e., the 'chain'
197 of agents involved in moving resources from supplier to customer) and not only of the first
198 'ground-level' link, because their profit may be marginal in comparison to that of the other links
199 along the supply chain, producing a biased view of overall profits on the natural resource.
200
201 *Data*
202 To determine attributes of the supply chains of gold and timber production, we drew on a decade
203 of nationwide official government data (e.g., state revenue of gold and wood, private gold profits,
204 rates of deforestation and degradation, Bank of Guyana 2015, GFC 2013, GoG 2015a, Guyana
205 Gold Board, cited by Thomas 2009). A general lack of public data on private (and sometimes
206 government) net costs and profits (respectively 'revenue') implied that for some data we had to
207 rely on single estimates, although sourced from experienced professionals (e.g., supply chain
208 analysis of logging profits (Bulkan 2012, Table 3), overall and cut-off gold grades (Swiecki

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2011, see Supplementary Note S3)), or stick to gross estimates (state revenue of gold and REDD+ income). On two occasions where no data existed, we made assumptions to provide insights (average gold grade of Guyana mining grounds, and recovery efficiency of mining operations, see Supplementary Note S3). In Section 4.3 we discuss the limitations and merits of this approach.

2.3 State revenue from national REDD+

We utilized Equation (1) to compute national gross REDD+ revenue under different emission scenarios, including Guyana's most recent (2014) documented emissions rate (GFC and INDUFOR 2015, GoG 2015a). 'Gross' revenue implies excluding all running costs of a national REDD+ mechanism (e.g., for monitoring emissions, reporting, administration), as estimates of these costs were not available for Guyana. For comparability, we used the gross income of the logging and gold mining sector, and note that the proportional costs of REDD+ and of these sectors may differ. We derived Total State revenue from the government's 2015 Budget presentation (GoG 2015b), which is corroborated by World Factbook figures (CIA 2014).

2.4 State revenue from the logging and gold mining sectors

State funds generated by the timber and gold mining sectors can be divided into direct income (royalty, acreage, license and export fees, fines), and indirect income (taxes on salaries and company incomes). For alluvial gold miners, a 2% tax on their gold sales is derived as income tax. Here we focus on direct state revenue as no sectoral tax revenue information was available in the public domain to aid computations. In addition, others (e.g., Ram 2011, Thomas 2012, Wilburg 2014) have suggested that indirect (i.e. theoretical) tax estimates may bear little relation to reality in Guyana and hence our computations did not include this element.

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Wood

The GFC (Guyana Forestry Commission) is the government body that handles all forestry sector activities and finances. Gross state revenue from commercial logging was calculated as the average gross income of the GFC over 2004—2012, as published in a series of Annual Reports released in 2013 (GFC 2013), converted to US dollars (Fxtop 2015). These reports also give the GFC's net revenue (83% less than gross revenue), which we used for a comparison of net revenues between the state and private sector (Table 3). The REDD+ opportunity costs of the logging sector were calculated by multiplying mean annual forest degradation emissions (GoG 2015a) by the interim price per metric ton of CO_2 set by Brazil's Amazon Fund (US$5, Joint Concept Note 2015).

Gold

Neither the mining oversight body, the Guyana Geology and Mines Commission (GGMC), nor the body that buys gold, the Guyana Gold Board (GGB), produced public financial statements over 2001—2012. Government gold mining revenues were instead estimated from royalty (5%) and tax (2%) on declared amounts of gold between 2001 and 2012 (Bank of Guyana 2015), multiplied by the mean annual gold price of the London Gold Bullion Market (Kitco 2016). Added to the gold revenue was an indirect estimate of rental revenue from mining permits, based on a value of $2.47 per ha per year (GGMC 2016), and the total permit area during this period sourced from various publications (Colchester et al. 2002, Guyana Times 2015, Stabroek News 2010, Thomas 2009). Our estimate corresponds well with a value presented by the GGMC to the United Nations Environmental Programme (GGMC 2010). The REDD+ opportunity costs of

mining were calculated by multiplying mean deforestation emissions of mining (GoG 2015a) by US $5.

2.5 Net revenues of state and private sectors

Wood

Net state revenue from logging was derived from available GFC annual reports from 2004 – 2012 (GFC 2013). Net private sector profit of the logging sector was sourced from Bulkan (2012) who examined the net present value per cubic meter of high-quality Wamara timber, *Swartzia leiocalycina*, along the logging value chain from forest road to end use as flooring in China and Europe.

Gold

Net State revenue of gold could not be determined due to lack of data on running costs of the GGMC and GGB (recent audit reports of these institutes were not available). Net profit of small/medium-scale gold mining was derived from the value of the declared volume of gold by subtracting 7% state taxes, the gold production cost estimated by the GGB (Thomas 2009) and 10% commission to permit holders (Lowe 2006).

Under declaration

Proportions of illegal extraction of wood were sourced from estimates by the World Bank, CIFOR/Iwokrama and the Government of Guyana (Clarke 2006, GoG 2015c, Trevin and Nasi 2009). Amounts of illegal and inefficient gold extraction was estimated from in-depth sector interviews and research (Falloon 2001, Harvard Law School 2007, Thomas 2009) and data from a mining expert and geological engineer in Guyana (Swiecki 2011), sustained by a simple

assessment of return-risk ratios (more detail in Supplementary Note S3).

3. Results

Using Equation (1) and Guyana's emission data (GoG 2015a), we found that gross national REDD+ revenue would at maximum be $231.5 million per year under a hypothetical emission rate of zero percent ((0.00242 – 0.000) * 19,134,623,287 tCO_2 * $5, Table 1). Using the most recent available emission rate of 0.065% in 2014 (GFC and INDUFOR 2015), REDD+ earnings would be $169.3 million per year. Guyana's total state revenue was $700.7 million in 2014 (GoG 2015b, exchange rate US$1 = G$206.50). This implies REDD+ would increase Guyana's total State revenue by 24.2% under current (2014) emission levels.

Table 1. Gross annual REDD+ revenue for Guyana under different emission scenarios (using Equation 1 [see above] and US$5 per tCO_2, GoG 2015a).

Emission scenario	Emission rate (%)	Annual revenue (million US$)	Annual avoided emissions (million tCO_2)
National historical rate (2001-2012)	0.049	184.6	36.9
Emissions in 2014 (most recent data)	0.065	169.3	34.0
No emissions	0.000	231.5	46.3
Total State revenue in 2014		700.7	

295 The timber sector yielded a mean annual $3.7 million in state revenue between 2004 and 2012
296 (range $2.7—$4.7 million, GFC 2013), and emitted an annual average of 3.9 million tCO_2 (Table
297 2). Under REDD+, the sector's emissions would cost the Government of Guyana $19.7 million
298 per year (emissions * $5) in foregone revenue.
299 State revenue from gold mining from 2001 to 2012 averaged $15.8 million from declared gold
300 (range $1.7 – 51.2 million, Bank of Guyana 2015), plus an estimated $3 million in rental income
301 from permits, for a total of $18.8 million (Table 2). The sector's opportunity costs under REDD+
302 would surpass this income by 22% ($22.9 million).
303
304 **Table 2. Mean gross state revenue, emissions and REDD+ opportunity costs per year (2001**
305 **-2012) of the timber and gold mining sectors in Guyana (at US$5 per tCO_2).**

Sector	State revenue (million US$.yr^{-1})	Emissions (million tCO_2.yr^{-1}) [a]	REDD+ opportunity cost (million US$.yr^{-1}) [b]
Timber	3.7 [c]	3.9	19.7
Gold mining	18.8 [d]	4.6	22.9

306 [a] Mean over the historical period 2001 – 2012 (GoG 2015a).
307 [b] Mean annual emissions * $5 (GoG 2015a).
308 [c] Mean over 2004 – 2012 (GFC 2013).
309 [d] 7% tax over the average declared gold production during 2001 – 2012 ($15.8M), plus an
310 estimate of rental revenue ($3M. See Methods for further explanation and sources).
311
312
313 Estimates of net profit to the private sector as well as revenue to the government from the logging
314 and gold mining sectors, using publicly available data, are provided in Table 3, with calculations
315 presented in the footnotes. Based on interviews with stakeholders along the logging supply chain
316 regarding their sale price and incurred costs, Bulkan (2012) estimated potential profits of $75 m^{-3}

317 for the chain segment 'transport from the hinterland forest road to the coastal capital city of
318 Guyana, Georgetown'. From 'Georgetown to 'Free On Board' (FOB) a ship in Georgetown's
319 harbor' another \$160 m^{-3} profit is realized, with \$333 m^{-3} more profit in 'shipment from Guyana
320 to China', and lastly, assuming a quarter profit margin, \$667 m^{-3} profit for flooring manufacturers
321 (derived from Bulkan 2012). This makes the cumulative private sector profit along the supply
322 chain (from forest road to retailer) \$1,235 m^{-3} (Table 3). The net state revenue of hardwood for
323 Guyanese society, in turn, was \$1.04 m^{-3} (\$6.11 m^{-3} gross, minus 83% to run the forestry
324 regulatory agency, GFC 2013). Additionally under REDD+, logging emissions will cost the State
325 43 times more in foregone revenue (Table 3). In terms of net state yield and overall employment
326 in the timber sector (22,561 jobs, GFC 2014), Guyana's forests have been logged for \$13 per
327 hectare, employing 0.5 persons. Under REDD+, the logging sector will cost Guyana \$547 per
328 hectare in state revenue (560 – 13, Table 3).

329

330 **Table 3. Private and State net revenue estimates and REDD+ costs of the timber and gold**
331 **mining sectors in Guyana, based on declared amounts (round US\$ figures, \$5 per tCO_2).**

Sector	Unit	Profit private sector	State revenue	REDD+ opportunity costs	Forest impacted ($ha.yr^{-1}$)
Timber	Cubic meter (logs)	235 [a]	1 [c]	43 [d]	
		1,000 [b]			
	Logged hectare [e]	3,075	13	560	46,000 [f]
		16,000			
Gold mining	Deforested hectare	29,000 [g *]	4,100 [h]	5,200 [i]	4,600 [j]

332 [a, b] Potential profit on wamara hardwood, *Swartzia leiocalycina*, for national (a) and
333 international (b) sections of the supply chain: a) road transport hinterland to 'Free on Board'

(FOB) in harbor of coastal capital Georgetown, and b) international shipping to flooring use in China, Europe (Bulkan 2012).

[c] $0.6M / 593,641 m^3 (mean net GFC revenue / mean annual wood production, (GFC 2013, GoG 2015a).

[d] (30.3/13) * (44/12) * $5 (tC logging emissions ha^{-1} / m^3 extracted ha^{-1} (Pearson et al. 2014)). '44/12' is C—CO_2 conversion factor.

[e] 13 $m^3.ha^{-1}$ (mean extracted volume per ha, Pearson et al. 2014).

[f] 593,641 $m^3.yr^{-1}$ / 13 $m^3.ha^{-1}$ (mean annual wood production / m^3 extracted ha^{-1}, (GoG 2015a, Pearson et al. 2014).

[g] $132.8M / 4,613 ha (Net private profit / mean mining deforestation yr^{-1}. Net profit is weighted mean value of annually declared gold – 10% permit commission – 7% State taxes – $270 oz^{-1} production costs. 1 oz. (troy ounce) = 31.1g (Bank of Guyana 2015, GoG 2015a, Lowe 2006, Thomas 2009). * See section 4.2 for a private profit estimate that includes an estimate of under declaration and inefficiency.

[h] $18.8M / 4,613 $ha.yr^{-1}$ (mean State revenue / deforested hectares, (GoG 2015a, Table 2). Note this is *gross* State revenue, i.e. the (unknown) running costs of the GGMC and GGB are to be subtracted from this amount.

[i] 283.7 $tC.ha^{-1}$ * (44/12) * $5 (mean C-stock per ha, GoG 2015a).

[j] 4,613 ha (mean mining deforestation yr^{--1}, GoG 2015a).

Gold production costs depend on several variables, and can range from around $1,250 per troy ounce (31.1g) according to the Guyana Gold and Diamond Miners Association (GGDMA, a local small - and medium scale miners' organization) (Guyana Times 2014) to just $77 per ounce by an efficient professional operation (Swiecki 2011, see Supplementary Note S3). We use the Guyana Gold Board's production cost estimate of $240—300 per ounce cited by Thomas (2009). After 7% State taxes, 10% commission for the permit holder, and assuming no exploration costs (Lowe 2006), using gold production levels declared to the government, we estimated that the mining sector earned a mean $29,000 net profit per hectare over 2001—2012 (Table 3). This is

7.1 times the $4,100 gross state revenue. Under REDD+, Guyana would forego $5,200 per hectare due to deforestation emissions. In terms of state yield and overall jobs attributed to the mining industry (13,000 jobs, GGMC 2010), Guyanese forests have been cleared for $4,100 (gross) per hectare employing 2.8 persons. Under REDD+, gold mining will cost Guyana over $1,100 per hectare in state revenue (Table 3).

4. Discussion

4.1 REDD+ competitiveness

Contrary to assertions that REDD+ is and will likely remain uncompetitive against current economic land uses (Boucher 2015, Butler et al. 2009, Pacheco et al. 2012, Turnhout et al. 2016, Wong et al. 2016), our analysis indicates that Guyana's national REDD+ program would add nearly a quarter more revenue to the national budget, outperforming the combined budget contributions of the gold and timber sectors. This is partially explained by Guyana's HFLD character (cf. Equation 1). However, we found the nation would also forego more REDD+ revenue than it earns on a hectare basis, even from high value forest commodities and at a modest interim carbon price. This discovery contradicts concerns about REDD+ being unable to compete financially against deforestation activities (Boucher 2015). We do not suggest that REDD+ can out-compete private profits (but see Section 4.1.1), but rather that it can out-compete sector returns received by the owner of the natural resources, in this case the state representing Guyanese society. We also discovered highly skewed benefit sharing between the private sector (favored) and the state from logging and gold mining. This sharing ratio is much further exacerbated when including estimates of under declaration and inefficiency in the gold sector (Section 4.2).

386

387 *4.1.1 Carbon density*

388 Besides its HFLD character, REDD+'s competitiveness in Guyana also benefits from the
389 comparatively high carbon density of its forests (284 $tC.ha^{-1}$, GoG 2015a): around double that
390 reported by other Amazon countries such as Brazil, Colombia, and Ecuador (UNFCCC 2017),
391 but in line with a southwest to northeast trend of increasing tree wood densities across the
392 Amazon basin (e.g., Ter Steege et al. 2006). This implies Guyana will receive about twice as
393 much revenue per avoided hectare of deforestation as these other countries. However, if carbon
394 prices increase 8-16 fold, as was recently concluded to be necessary by 2020 to meet the Paris
395 temperature objective (CPLC 2017, Carbon Tracker et al. 2017), this would more than
396 compensate twofold lower carbon densities. Such carbon prices ($40-80, or higher) would place
397 serious economic pressure on CFU in any natural forest: clearing even low carbon forest of e.g.
398 100 $tC.ha^{-1}$ would cost a country ~$15,000 – 30,000 per hectare in forgone REDD+ revenue (100
399 * 44/12 * $40-80).

400

401 *4.1.2 Land grabbing*

402 Under Equation 1, based on Guyana's UN-approved FREL submission, national REDD+ will
403 generate negligible to no forest rent, hence provide little incentive for land grabbing (e.g.,
404 Sunderlin et al. 2014), because the multiplication factor '(REL – AEL)' in Equation 1 implies
405 that if there are no reductions in a given year (REL = AEL), this factor becomes zero and no
406 revenue is made on any hectare of standing forest. If, for example, a country's REL is near the
407 global average, 0.4%, and its AEL in a given year is 10% below that (0.36%), then revenue made
408 for a hectare of forest (of say 200 tC) is given by: [0.0040 – 0.0036] * 200 * (44/12) * $5 =
409 $1.47 ha^{-1}. Even an ambitious 50% reduction (AEL = 0.2% in our example) would yield a mere

410 $7.33 ha^{-1} forest rent that year, which is unlikely to become a motivation for land grabbing; more
411 so, since damaging forest will cost the owner (or the State) $5,200 when cleared, and $560 when
412 logged in forgone REDD+ revenue (Table 3). National REDD+ appears not to 'put value' on
413 standing forest, but financial penalties on forest damages (clearing or degradation). Governments
414 should take measures against *pre*-REDD+ land grabbing (acquire now, convert later), as the state
415 will incur foregone revenue costs upon conversion.
416

417 **4.2 Underdeclaration and inefficiency**

418 In the context of our analysis of private-state revenue sharing, the implications of under
419 declaration of products should be considered. The volume of wood that goes undetected through
420 the system in Guyana is estimated at 2—15% (Clarke 2006, GoG 2015c, Trevin and Nasi 2009),
421 and at 25—400% for the gold sector; this amounts to a quarter to four times the declared amount
422 (Falloon 2001, Harvard Law School 2007, Thomas 2009). Exact estimates of under-declared
423 amounts are by nature impossible, but in Supplementary Note S3 we suggest that incentives to
424 under-declare along the supply chain, combined with inefficient gold recovery, may well have
425 resulted in Guyana having lost revenue from gold volumes beyond four times what was declared
426 during 2001—2012. Based on our estimate (479%), missed state revenue may have averaged $76
427 million per year (4.79 * $15.8M, Table 2, peaking to $245M in 2012). It implies that average net
428 private profit over this period was, or could have been with professional mining, $264,200 per
429 hectare, i.e. not 7x but 65x more than the gross revenue for the state ($4,100, Table 3, Suppl.
430 Note 3).
431

432 **4.3 Potential of cleaning profit chains, and employment**

433 We observed extreme levels of discrepancy in benefit sharing of natural resources between state
434 and private sector supply chains, with net state shares of <1.5% for gold, and 0.08% for wood
435 (derived from $4,100 / [$264,200 + $4,100] for gold (Section 4.2), and $1 / $1,235 for wood
436 (Table 3)). Despite uncertainty around the exact values of private gains for lack of public figures,
437 the discrepancies observed are so extreme that, at a minimum, it would warrant further research.
438 As it stands, Guyana as a country receives little net revenue from the exploitation of its natural
439 resources, and it would lose substantially more in foregone revenue under REDD+ due to CFU-
440 associated forest emissions (Tables 2, 3).
441 Second, although the notion of gold smuggling and low state proceeds of logging are widely
442 known and reported in Guyanese news media (e.g., Kaieteur News 2014, Stabroek News 2015),
443 ours are the first reasonably plausible countrywide estimates of overall net annual revenue for the
444 two main forest-based resources, and how it is shared between the 750,000 owners (Guyana's
445 population) and the company owners or individuals representing the links of the supply chains.
446 Our findings on revenue sharing have further implications for REDD+. First, at a minimum gold
447 and wood supply chains appear able to contribute in bearing the costs of emission reduction
448 measures and enhanced forest rehabilitation (cleaning supply chains), *in lieu* of claiming the
449 REDD+ credits as compensation. Our emphasis is on supply chains as a whole and not just the
450 first link at the ground level.
451 Second, the modest per hectare state revenue and employment figures of CFU (logging $13 ha^{-1},
452 0.5 jobs, gold mining $4,100 ha^{-1} gross, 2.8 jobs) should also, from the government's perspective,
453 ease land use conflicts between CFU and forest-dependent peoples (FDP) on titled or customary
454 lands, given that CFU are typically associated with large long-term damage to livelihoods and
455 social disruption in communities of the first inhabitants, next to environmental damage
456 (Colchester et al. 2002). Declining or revoking commercial permits on FDP-lands would

457 simultaneously demonstrate adherence to mandatory REDD+ social safeguards, i.e. respecting
458 indigenous rights.
459 Third, the observed small state yields on these commodities indicate that government
460 interventions towards more equitable distribution, or 'cleaning profit chains', are both well-
461 justified and would be well-worth the effort. Just a 1% share increase (i.e. from the current ~1%,
462 to 2%) would *double* state revenue from this sector annually. It is beyond the scope of this paper
463 to elaborate on possible interventions, as these will be dependent on country-specific
464 circumstances. In general, interventions in Guyana's gold sector could best focus on reliable law
465 enforcement and professionalization of the sector (Supplementary Note S3). In the forestry
466 sector, higher FOB prices may be possible if, to avoid 'logging company leakage', producer
467 countries can come to collective agreement on their globally highly demanded resource, while
468 advances in remote sensing resolutions and drone technology may soon significantly reduce
469 illegal logging through remote monitoring of individual tree gaps in logging concessions,
470 combined with emission factors (e.g. 30cm, DigitalGlobe 2017, Mitchell 2014, Pearson et al.
471 2014).
472 Interventions towards more equitable revenue sharing should not affect employment or
473 production since they are targeted at profits, which arise as a product of the labor, and after
474 production. Neither would they reduce emissions directly. Governments can however use the
475 significant extra state revenue of such interventions for investments in better forest management,
476 law enforcement, anti-corruption measures, declining CFU proposals with marginal country
477 benefits, exploration surveys in gold mining, etc. To give some perspective on the order of
478 magnitude of overall gold revenues, the 1.5% state share reflects $15.8M (Table 2, note 'd'),
479 implying that around $1 billion worth of gold *profit* (not gold value) may have been extracted per
480 year from Guyana's soils during 2001—2012. This equals almost 1.5 times the entire 2014 state

budget (GoG 2015b). As such, next to cleaning supply chains and moving commodity production out of primary forest areas (e.g. Boucher et al. 2011, Strassburg et al. 2014, UN Climate Summit 2014), cleaning profit chains may be another option for potentially very large, and homegrown, state funds for investments in the rational and lawful use of finite natural resources. Such investments would not just be a cost but, next to creating law enforcement and accounting jobs, would return substantial REDD+ credits for mitigating climate change.

Lastly, since 'national REDD+' is not yet operational worldwide, and hence carbon credits to HFLD countries such as Guyana for preventing international leakage and rewarding good past forest stewardship may realistically even be further off, making the cleaning of profit chains a domestic option is something developing countries do not have to wait for.

4.3.1 Beyond Guyana, and beyond REDD+

While the particular ratios of revenue sharing will be unique to Guyana, the general phenomenon of unequal private-state sharing on natural resources is likely not, since one main cause or facilitating factor, poor (interior) law enforcement, is common in perhaps all developing countries (e.g., Dimant 2013, Lambin et al. 2001). Low risk on high returns, due to lacking, easily bribed or intimidated law enforcement, forms a very strong incentive for illegal practices, while the accumulating returns can be directed to economic and political leverage to undermine any plan that would interfere with these income streams, including national REDD+, rural social development, customary land rights, or conservation plans (e.g. Brockhaus et al 2014).

Estimating net revenue sharing along supply chains of forest commodities in other countries may therefore provide valuable insights into potential cures.

Changing the status quo of vested economic and political interests is difficult and possibly dangerous (Global Witness 2017), but levels of motivation for change (by government and/or

505 electorate) could be harnessed through an awareness of inequity, levels of financial return from
506 interventions and levels of risk. With the Guyana case study we have attempted to begin
507 estimating the order of nation-wide long-standing inequity in net revenue sharing, and indicate
508 potential returns.
509 Assessing and 'equitizing' revenue ratios of forest-based natural resources, or cleaning profit
510 chains, may not only be helpful to generate funds for emission reductions, but may also aid the
511 performance of rural conservation and social development efforts including land tenure, more so
512 since 'equitizing' produces state finance.
513

514 **5. Conclusions**

515 We present the first detailed look at a REDD+ program implemented at a national level. We
516 describe the components of a national REDD+ program that serve to reduce forest emissions and
517 increase financial returns to resources owners. The approval of Guyana's program by the United
518 Nations (GoG 2015a,b) demonstrates that even low-income developing countries can be effective
519 partners in combating climate change. In general, national REDD+ appears to not so much 'add
520 value to forest' but impose a financial penalty for forest damage. This should eliminate
521 incentives for land grabbing. REDD+ in Guyana is not only viable but also competitive from the
522 perspective of the owner of the exploited natural resources. Gold and logging sectors would cost
523 more in foregone revenue under REDD+ than they yield the state per hectare, even at US $5 per
524 tCO_2. The skewed (~1 : 99) benefit sharing of forest-based commodities between the state and
525 private sectors in favor of the latter indicates that interventions are warranted and worthwhile.
526 Poor law enforcement in the interior contributes to the skewedness in returns. Such ratios likely
527 exist in many other tropical countries and this situation likely hampers rural development.
528 Interventions in support of more equitable revenue sharing should not affect employment or other

inputs into the economy as profits arise as a product of production and labor. Interventions should instead provide homegrown financing for investment in rational and lawful use of finite forest-based natural resources, and return REDD+ income by helping mitigate climate change. The projected levels of carbon prices deemed necessary to meet the Paris temperature target would likely push most commodities out of tropical forests to lower carbon landscapes. These economic findings and developments should improve the livelihoods and rights of forest-dependent people.

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Author contributions

HO conceived, researched and analyzed this study, with contributions from ARC, JBL, and JMVF. HO lead writing with contributions from ARC, JBL, and JMVF in completing the manuscript.

Competing financial interests

The authors have declared that no competing financial interests exist.

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