LETTERS

# Tropical Deforestation and Carbon Emissions from Protected Area Downgrading, Downsizing, and Degazettement (PADDD)

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**Keywords**
Biodiversity; climate change mitigation; deforestation; ecosystem services; forest carbon; land tenure; national park; PADDD; protected areas; REDD+.

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**Received**
14 April 2014
**Accepted**
16 August 2014

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doi: 10.1111/conl.12144

## Abstract

Protected area downgrading, downsizing and degazettement (PADDD) is a global phenomenon that has not received formal attention in Reducing Emissions from Deforestation and Forest Degradation (REDD+) policies designed to reduce forest carbon emissions and conserve biodiversity. Here, we examine how PADDD affects deforestation and forest carbon emissions. We documented 174 enacted and 8 proposed PADDD events affecting more than 48,000 km$^2$ in three REDD+ priority countries: Democratic Republic of the Congo, Malaysia, and Peru. Where sufficient data were available, we estimated deforestation rates and the quantity and economic value of forest carbon already lost and at risk in three land tenure classes: PADDDed, protected, and never-protected. PADDDed forests experienced deforestation and forest carbon emissions greatly exceeding rates in protected areas and slightly exceeding rates in never-protected forests. PADDD represents business-as-usual for protected areas, posing substantial risk to forests and forest carbon stocks. REDD+ policies have substantive implications for protected area biodiversity and forest carbon emissions; the Warsaw Framework for REDD+ provides new, but insufficient, guidance for nations to address these issues.

## Introduction

Atmospheric concentrations of carbon dioxide ($CO_2$) are approaching 400 ppm, ~40% greater than prior to the Industrial Revolution (IPCC 2013). To mitigate $CO_2$ emissions, climate change, and the resultant ecological and social impacts, public and private sector actors are implementing diverse strategies (Metz *et al.* 2007). Central to these mitigation strategies are efforts to reduce $CO_2$ emissions from deforestation and forest degradation, which represent approximately 10% of annual global greenhouse gas emissions (IPCC 2013). Reducing Emissions from Deforestation and Forest Degradation (REDD+) is an emerging international framework whereby donor countries compensate developing countries based on reductions in $CO_2$ emissions realized through forest conservation and restoration (UNFCCC 2011).

  

Within the international REDD+ policy framework, individual countries may develop their own national systems for carbon accounting, which may or may not include protected areas (UNFCCC 2014). Since protected areas cover nearly 20% of tropical forests, appropriate treatment of protected areas is a critical element of effective REDD+ policies (Scharlemann *et al.* 2010). Protected areas are also often planned explicitly to protect natural forests and biodiversity, which are forest carbon cobenefits that Parties to the United Nations Framework Convention on Climate Change (UNFCCC) were encouraged to address in the 2010 Cancún agreement (UNFCCC 2011), and report on under the 2013 Warsaw Framework for REDD+ (UNFCCC 2014). However, scientists and decision-makers debate the role of protected areas within REDD+ policies. Protected areas may be considered permanent storehouses of forest carbon with limited prospects for *additional* reduced emissions or, conversely, subject to legal and illegal activities that cause substantial carbon emissions and threaten cobenefits (Ricketts *et al.* 2010; Sunderlin & Silis 2012). Some suggest that *allowing* protected areas to be eligible for REDD+ funding may create perverse incentives to disregard environmental laws (Börner & Wunder 2008), while others argue that *failure* to recognize protected areas within a REDD+ policy framework may create perverse incentives, such as for protected area downgrading, downsizing, and degazettement (PADDD; Mascia & Pailler 2011). PADDD is a widespread phenomenon that challenges the paradigm that protected areas are indeed permanent (Mascia & Pailler 2011; WWF 2013; Mascia *et al.* 2014). To date, however, researchers have not empirically examined the implications of PADDD for REDD+ policies.

To inform this debate, we examine the impacts of PADDD on tropical deforestation and forest carbon emissions in three high priority REDD+ countries with large forest carbon stocks (van der Werf *et al.* 2009; FAO 2010), high biodiversity (Kier *et al.* 2009), and substantial numbers of PADDD events: Democratic Republic of the Congo (DRC), Malaysia, and Peru. These countries represent ~10% of annual global forest loss and ~7.6% of global forest carbon emissions (van der Werf *et al.* 2009; FAO 2010). These countries are extraordinary from a biodiversity perspective, though this biodiversity is also highly threatened (Mittermeier *et al.* 1998; Olson & Dinerstein 1998). In this study, we (1) conducted archival research to document enacted and proposed PADDD events in each country since 1900; (2) analyzed historical rates of deforestation and forest carbon loss within PADDDed lands in Peninsular Malaysia and Peru, compared to corresponding rates within protected areas and never-protected forests; and (3) examined the economic net present value (NPV) of forest carbon under 3 emissions and 3 carbon price scenarios. Results illustrate the ecological implications and opportunity costs of PADDD, and provide insights about the role of protected areas in REDD+ policy.

## Methods

### Data collection and preparation

We created a comprehensive database of enacted and proposed PADDD in DRC, Malaysia, and Peru. The database consists of all available information on PADDD events, including protected area name, location and area affected (including boundaries), type (whether downsized, downgraded, or degazetted), year, and proximate cause (Table S1). To create the database, we conducted a comprehensive review of the protected area systems from 1900 to 2011, reviewing protected area legislation in all three countries and administrative journals in DRC. For information on spatial area affected, we digitized historic maps of PADDD events and protected areas from government sources, as available.

### Calculating deforestation and forest carbon loss following PADDD events

We assessed the amounts and rates of deforestation and carbon loss following PADDD events in Peninsular Malaysia and Peru, compared to protected areas and areas that had never experienced protection. PADDD events in these geographies included only downsizings and degazettements.

We based our analysis on four datasets: (1) areas affected by PADDD; (2) the current protected area networks of Peru (SERNANP 2011) and Peninsular Malaysia (IUCN & UNEP-WCMC 2013; Malaysia Ministry of Natural Resources and the Environment, unpublished work); (3) above-ground biomass for the year 2007 (Baccini *et al.* 2012); (4) Forest cover change, derived from Vegetated Continuous Fields v005 data from 2000 and 2010 (Defries *et al.* 2000; Hansen & DeFries 2004; DiMiceli *et al.* 2011) in Peru (Figure S1), and land cover maps for 2000 and 2010 in Malaysia (Miettinen *et al.* 2011; Miettinen *et al.* 2012). We determined the total forest cover lost (ha), total forest carbon lost (Mg), and annual percent of original (year 2000) forest cover and forest carbon lost by land tenure class (PADDD, protected, never-protected).

 

### Scenarios of future forest carbon emissions

For Peninsular Malaysia and Peru, we next estimated the impact that protection and PADDD could have on above-ground carbon stocks by the year 2100, compared with areas that had never experienced protection. We did this by exploring three scenarios: Scenario (1) *Observed Business-as-Usual (BAU):* 2000–2010 observed rates of forest carbon loss proceed to 2100; Scenario (2) *FAO National BAU*: 2000–2010 rates of deforestation (FAO 2010) proceed to 2100; and Scenario (3) *Full Conversion*: All standing forest is converted to nonforest by 2100. We did not include proposed PADDD events in these analyses, because we were unable to isolate the exact areas proposed for excision.

### Carbon valuation scenarios

For Peninsular Malaysia and Peru, we calculated the discounted NPV of forest carbon in each land tenure class to the year 2100 under three carbon emissions and three estimates of the unit cost of carbon (to account for uncertainty in carbon value). From a market or private standpoint, carbon was trading at approximately \$37/Mg C on the European Union Emissions Trading Scheme, and approximately \$3.70/ Mg C for Certified Emissions Reductions under the Clean Development Mechanism of the Kyoto Protocol. Carbon shadow prices from a social standpoint, derived from models that estimate the social damages from climate change, are similarly variable (Tol 2005; Tol 2011), including medians of \$14/ Mg C (Tol 2005) or \$57/ Mg C (Tol 2011), and "best guess" estimates of \$5/ Mg C. Accordingly, we use low, medium, and high carbon price figures of \$3.70/Mg C, \$14/Mg C, and \$57/Mg C to capture this variability in our carbon value calculations. We projected forest carbon value annually from 2010 to the year 2100, using the three values of carbon and a discount rate of 5%. We defined "additionality" as the difference between anticipated carbon loss in each of the above-described carbon emissions scenarios and a REDD+ project that results in zero emissions. By applying a scenario approach, we emphasize a range of potential NPV as a way of expressing relative value of PADDD areas to protected and unprotected areas, and also uncertainty.

Similarly, we estimated the value of carbon lost between 2000 and 2010 in each land tenure class by multiplying the observed average annual amount of carbon lost each year by the three market values of carbon, and projecting the discount rate forward from the year 2000.

### Regression analysis of deforestation drivers

Biophysical characteristics and accessibility are significant predictors of forest loss (Geist & Lambin 2002), and various approaches have been proposed to control for these factors while assessing the role of management for avoiding deforestation (Cropper *et al.* 2001; Deininger & Minten 2002; Mas 2005; Andam *et al.* 2008; Pfaff *et al.* 2014). We conducted regression analyses to further test the hypothesis that PADDD is a significant predictor of deforestation in Peninsular Malaysia and Peru, while controlling for biophysical characteristics and accessibility. Consistent with the deforestation analysis described earlier in this study and using best available data, we selected change in canopy cover from 2000 to 2010 as the dependent variable in Peru (DiMiceli *et al.* 2011), and forest loss as the dependent variable Peninsular Malaysia (Miettinen *et al.* 2011). Independent variables included topography (elevation, slope), accessibility (distance to major roads, city centers, and major rivers), and protection status (PADDDed, protected, never-protected). (See Supplemental Information for detailed Methods).

## Results

### DRC

Since 1900, DRC has experienced 39 PADDD events: six downgrades (15.3%), two downsizes (5.1%), and 31 degazettements (79.5%), affecting 36 protected areas (occurrence per protected area: mean = 1.1; $SD = 0.37$; median = 1; mode = 1; Table 1). Most DRC PADDD events consist of degazetted forest reserves in the late 1950s (Figure 1). Proximate causes of enacted PADDD events are rarely reported, but include infrastructure, mining, and agriculture. At least three PADDD events have been proposed but not yet enacted in DRC (Table S2). We were unable to determine the size and spatial location of PADDD events based on data in DRC archives.

### Malaysia

Malaysia has experienced at least 121 PADDD events since 1900, including 110 events in Peninsular Malaysia, 10 in Sabah, and one in Sarawak. These 121 PADDD events affected 20 protected areas (occurrence per protected area: mean = 6.1; $SD = 13.2$; median = 1; mode = 1) and >3,145 km$^2$ (mean = 34.5 km$^2$; $SD$ = 138.8 km$^2$), which represents ~5% of Malaysia's potential protected area estate (per Mascia *et al.* 2014) and 0.1% of Malaysia's land mass (Table 1). Seven protected areas experienced more than one PADDD event, with a maximum of 54 PADDD events affecting Endau-Kota Tinggi Wildlife Reserve. Most PADDD events were

**Table 1 Enacted PADDD events in Democratic Republic of Congo (DRC), Malaysia, and Peru.** Number of protected areas (PAs) affected by PADDD are in parentheses. ND = no data

| | | DRC | Malaysia | Peru |
|---|---|---|---|---|
| Number of enacted PADDD events (and affected PAs) | | | | |
| | Downgrade | 6 (4) | 0 | 0 |
| | Downsize | 2 (2) | 109 (11) | 4 (4) |
| | Degazette | 31 (31) | 12 (11) | 10 (10) |
| | Total | 39 (36) | 121 (20) | 14 (14) |
| Area affected by PADDD ($km^2$)[a] | | | | |
| | Downgrade | ND | 0 | 0 |
| | Downsize | ND | 2,428 | 30,532 |
| | Degazette | ND | 717 | 14,871 |
| | Total | ND | 3,145 | 45,403 |
| Percentage PA estate affected | Total | ND | 4.98% | 21.54% |
| Percentage national terrestrial area affected | Total | ND | 0.10% | 3.53% |
| Proximate cause of PADDD | | Infrastructure, 2<br>Forestry, 1<br>Subsistence, 1<br>Degradation, 1<br>Building materials, 1<br>Land sales or licenses, 1<br>Unknown, 32 | Industry, 1<br>Settlement, 1<br>Mining, 1<br>Unknown, 118 | Logging, 13<br>Unknown, 1 |

[a] GIS data were used to calculate area affected when available; otherwise, we used reported areas.

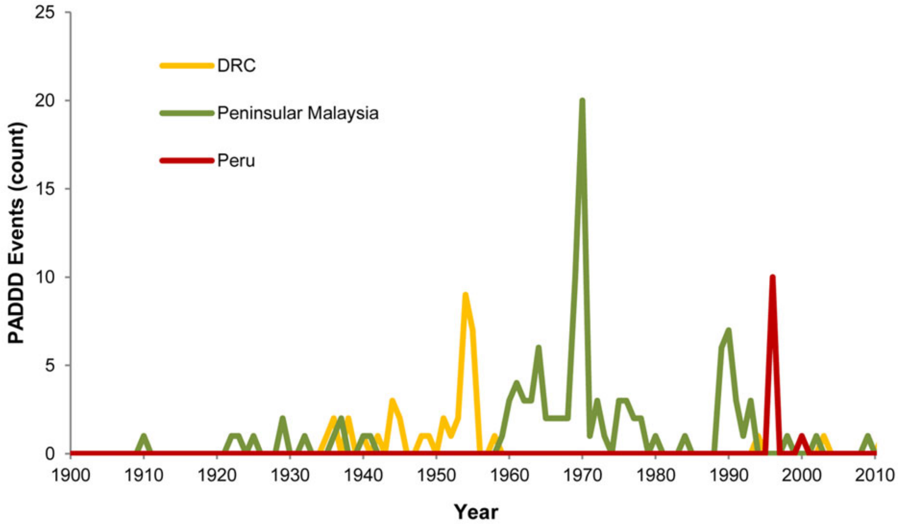


**Figure 1 Timeline of enacted PADDD events in Democratic Republic of the Congo (DRC), Malaysia, and Peru.** The first protected area designated in DRC was in 1905 (IUCN and UNEP-WCMC 2013), Malaysia in 1903 (Perak Government 1903), and Peru in 1961 (SERNANP 2011).

protected area downsizes ($n = 109$, 90%); the remainder were degazettements ($n = 12$, 10%). Most Malaysian PADDD occurred in the 1960s and 1970s (Figure 1). Proximate causes of PADDD in Malaysia were rarely reported, but include industrialization, rural settlements, and mining; most converted forest in PADDDed lands is now plantation (Figure S2). We documented one proposed PADDD event in Malaysia, occurring in Sabah (Table S2). We were unable to determine the spatial location of enacted and proposed PADDD events in Sabah and Sarawak, so analyses focus on Peninsular Malaysia.

In Peninsular Malaysia, PADDD accelerated deforestation and forest carbon emissions. From 2000 to 2010, PADDDed forests exhibited an estimated 240% higher deforestation rate compared with protected forests (270% higher carbon emissions), and a 7% higher rate

 

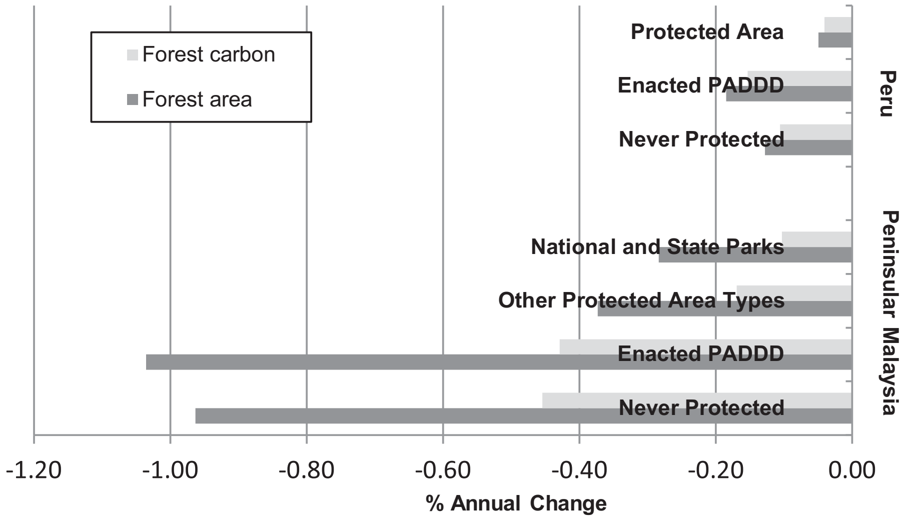


**Figure 2 Estimated annual percent change in forest cover and forest carbon in Peninsular Malaysia and Peru (2000–2010).** PADDD areas in both countries experienced slightly higher rates of deforestation than never protected areas, and much higher rates than areas under protection.

compared with never-protected forests (6% lower carbon emissions) (Figure 2 and S3; Table S3). PADDDed forests emitted approximately 1.5 million Mg C from 2000 to 2010, with values from ~\$4.5 to \$69.6 million (Table S3). Regression models further suggest that PADDD is a significant predictor of forest loss in Peninsular Malaysia, even when controlling for biophysical characteristics and accessibility (Table S4).

If future deforestation rates follow recent trends, PADDDed forests would emit approximately 6.0–10.9 million Mg C by 2100; if all forest is converted, emissions from PADDDed forests could reach ~21.8 million Mg C. The estimated NPV of these emissions ranges from \$5.6 to \$152.5 million if additionality is based on past emissions (Scenarios 1 and 2), or up to \$273.1 million if all forest carbon in PADDD areas is considered at risk of conversion (Scenario 3). In protected areas, forest carbon NPV ranges from ~\$17.1 to \$524.7 million under Scenarios 1 and 2, and up to \$1.2591 billion under Scenario 3 (Figure 3; Table S5).

## Peru

Fourteen PADDD events have occurred in 14 Peruvian protected areas (occurrence per protected area: mean = 1; $SD = 0$; median = 1; mode = 1), affecting ~45,000 km$^2$ and resulting in the permanent loss of ~34,000 km$^2$ of protected areas (mean = 2,261 km$^2$; $SD = 2{,}827$ km$^2$). Thirteen PADDD events occurred in 1996, when National Forests were removed from the Peruvian protected area system in order to open them to commercial logging (Peru Ministry of Agriculture 1996; Figure 1). Portions of four degazetted National Forests were later regazetted as national parks or sanctuaries, so these functionally served as downsizing events. Altogether, Peru has experienced ten degazettements (71%) and four downsizes (29%; Table 1). Three additional downsizes (for petroleum exploration or mining) and one additional degazettement (for lack of biological representativeness) have been proposed in Peru since 2003 (Table S2). The total area affected by enacted PADDD events comprises 23% of the potential protected area estate. Seventeen percent of the historic protected area system has been lost permanently as a result of PADDD, representing 4% of Peru's total land area.

From 2000 to 2010, deforestation and carbon emissions rates in Peruvian PADDDed forests were both estimated to be 275% higher than in protected forests, and 45% higher than in never-protected forests (Figure 2 and S3; Table S3). PADDDed forests emitted ~10.0 million Mg C from 2000 to 2010, valued at \$29.8–\$459.2 million (Table S3). Regression models further suggest that PADDD is a significant predictor of canopy cover change in forest areas, even when controlling for biophysical and accessibility factors (Table S6).

If future deforestation rates follow recent trends, PADDDed forests in Peru would emit approximately 91.5-94.9 million Mg C by 2100 and, if all forest is converted, emissions could reach 610.9 million Mg C. These emissions represent a NPV of \$78.0 million to \$1.2392 billion under scenarios based on past emissions (Scenarios 1 and 2), or up to \$7.6619 billion if all forest carbon

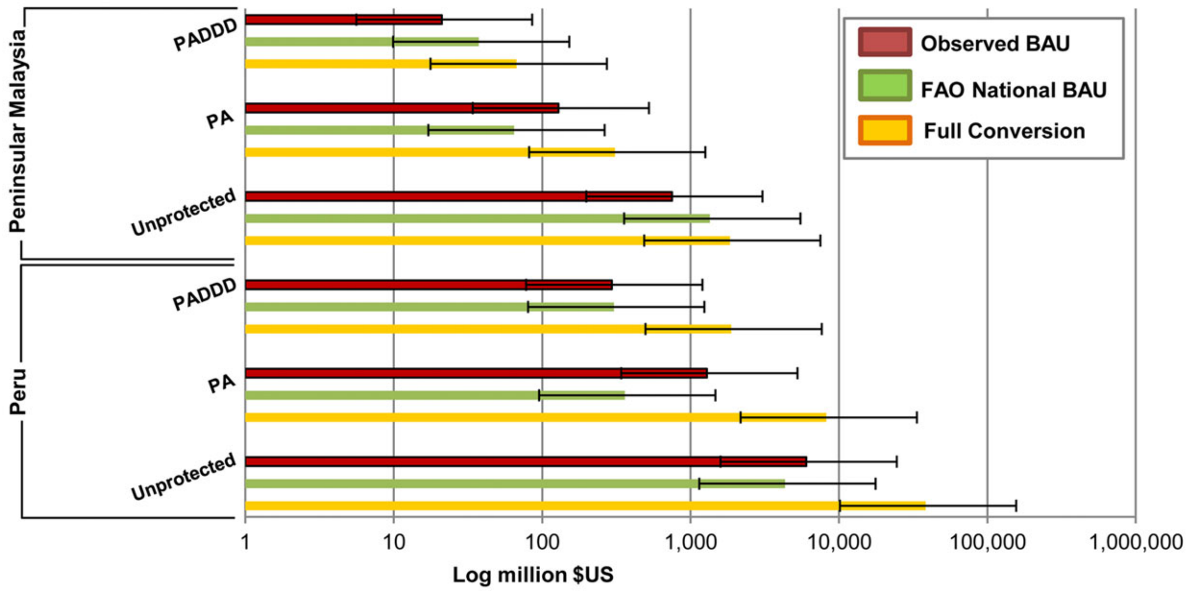


**Figure 3 Estimated net present value (NPV) of forest carbon sequestered to the year 2100 in Peninsular Malaysia and Peru,** under three carbon emissions scenarios and three market values of carbon.

in PADDD areas is at risk (Scenario 3). In protected areas, the value of forest carbon ranges from $95.5 million to $5.2584 billion under Scenarios 1 and 2, and up to $33.5168 billion under Scenario 3 (Figure 3; Table S5).

## Discussion

These findings demonstrate that PADDD has substantive implications for biodiversity conservation and provision of ecosystem services, extending initial research that characterized PADDD and its patterns, trends, proximate causes, and treaty implications (Mascia & Pailler 2011; Mascia *et al.* 2014). Given that PADDD may result in dramatically higher deforestation rates and forest carbon emissions, the impermanence of protected areas represents a profound challenge for conservation policy and practice. Potential conservation policy responses to the risk of PADDD include greater investment in protected area implementation, management, and legal sustainability; more robust protected area networks; and more diversified portfolios of conservation strategies (e.g., protected areas, community-based natural resource management, payments for ecosystem services, environmental certification regimes, etc.; Mascia & Pailler 2011; Mascia *et al.* 2014). In the absence of comprehensive environmental safeguard policies, public and private sector banks, extractive industries, and other organizations may need to develop standards that address PADDD. Similarly, government agencies and legislatures may need to develop formal legal processes that govern PADDD, in parallel to the legal processes that govern protected area planning and establishment. The complex social and environmental trade-offs implicit in PADDD events also require further scientific understanding and public dialogue about PADDD and its implications.

In particular, with respect to the development and implementation of REDD+, our findings highlight the need to consider protected area and PADDD dynamics when estimating carbon fluxes and developing policy responses. High carbon emissions rates from PADDDed forests suggest that they represent priorities for *additional* emissions reductions (Ricketts *et al.* 2010). PADDDed lands may also have ecological values comparable to, or supportive of, existing protected areas (Groves *et al.* 2002; Hansen & DeFries 2007). With the potential for high emission reductions with correspondingly high biodiversity conservation cobenefits (Phelps *et al.* 2012), PADDDed areas may thus represent possible REDD+ win–wins. However, the occurrence (and sometimes recurrence) of PADDD may reflect dynamic or unstable land governance, possibly limiting the potential for *permanent* reductions in carbon emissions in these lands and the cost effectiveness of potential REDD+ interventions (Naidoo *et al.* 2006; Polasky 2008). Existing protected areas, by contrast, may represent less opportunity for achieving large emissions reductions, but greater likelihood of permanent emissions reductions. Thus, a portfolio approach to emissions reductions under REDD+ policies may help to hedge risk

 

(Hoekstra 2012) associated with potential additionality-permanence trade-offs. At the same time, our experiences in DRC and insular Malaysia demonstrate that documenting PADDD and BAU protected area emissions scenarios may present a substantial challenge.

The Warsaw Framework for REDD+ outlines the process by which countries should report on the status of cobenefits to carbon that they are encouraged to "safeguard" (e.g., natural forests, biodiversity, indigenous peoples' livelihoods, ecosystem services; UNFCCC 2011, 2014). However, little guidance exists on *how* countries should monitor and report on the status of cobenefits. Under such a system, how would auditors know that the "plus" in REDD+ is actually improving? For protected areas, countries could optionally monitor and report on deforestation rates within protected area and PADDD forests as an indicator of biodiversity, natural forests, and specific forest-dependent ecosystem services. If deforestation and degradation rates decrease in these areas over time, relative to the baseline, this would suggest positive implications for biodiversity cobenefits. Parties could also monitor and report on protected area permanence (and, conversely, PADDD) as an indicator of biodiversity and other protected area-associated cobenefits; countries with high rates of PADDD may be performing poorly at safeguarding biodiversity. In addition, protected area permanence (and, conversely, PADDD) may be an indicator of governance, which has implications for the success of REDD+ projects. Not only will monitoring and reporting on safeguards specific to the protected area estate help to fulfill the safeguard protocol under REDD+, but this approach could also facilitate "premium" investments in REDD+ that link emission reductions with biodiversity cobenefits (e.g., Dinerstein *et al.* 2013).

Failure to consider protected area and PADDD dynamics may lead to perverse outcomes. REDD+ policies that simply *ignore* protected areas would presumably be vulnerable to historic (pre-REDD+) PADDD dynamics, with increasing forest carbon emissions within PADDDed lands. REDD+ policies that intentionally *exclude* protected areas from national emissions baselines and monitoring, reporting, and verification (MRV) systems may exacerbate leakage of deforestation and forest degradation into protected areas, either through PADDD (Mascia & Pailler 2011) or illegal extraction (Sunderlin & Silis 2012). This leakage could be accelerated by forest management activities that shift away from natural forests in protected areas to forests with highest baseline emissions rates, where there is greatest opportunity for additional emission reductions (Grainger *et al.* 2009; Harvey *et al.* 2010).

Implementing such safeguard monitoring systems will require improved national-level tracking of protected areas and PADDD, as well as the forest and carbon dynamics within them. Beyond REDD+, nationally and globally strengthened protected area and PADDD databases (e.g., IUCN & UNEP-WCMC 2013; WWF 2013) will be crucial for transparency and governance, as the demands for natural resources associated with PADDD are likely to increase in the future (Lambin & Meyfroidt 2011; Mascia & Pailler 2011). Data on protected area trends and forests will also be critical for generating an improved understanding of the ecological and social impacts of protected areas, since most protected area research to date has considered protected areas as static features rather than dynamic systems (Miteva *et al.* 2012). More generally, our findings highlight the impermanence and unintended consequences of environmental regimes (Mascia *et al.* 2014). Robust social and environmental safeguards, comprehensive carbon accounting, rigorous MRV systems, and mechanisms for periodic policy reforms are necessary for climate policies that achieve desired ends while minimizing prospects for unintended consequences and perverse outcomes.

## Acknowledgments

We thank the Gordon and Betty Moore Foundation for financial support and ESRI for GIS software. The online Data Pool at the NASA LP DAAC, USGS/EROS Center provided MODIS 44B data; A. Shapiro and H. Kuechly pre-processed these data for subsequent use. C. Pelissier, P. de Marken, R. Maqbool, S. Suksuwan, W. Wan Ishak, and D. Anthony assisted with data collection, coordination and interpretation. N. Aguilar-Amuchastegui, R. Naidoo, D. Pennington, L. Glew, and J. Niles provided advice related to REDD+ and analytical approaches.

## Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

**Figure S1**. Percent canopy cover values from VCF 2000 data compared with a Landsat-based land cover classification for Peru in the year 2000.

**Figure S2**. Land cover distribution in Peninsular Malaysia and Peru in the year 2000 by land tenure type.

**Figure S3**. Forest carbon change 2000–2010 in Peninsular Malaysia and Peru.

**Table S1**. PADDD database fields.

**Table S2**. Proposed PADDD events in DRC, Malaysia, and Peru.

**Table S3**. Observed historical loss of forest area, forest carbon, and estimated NPV of amount lost (2000–2010) in Peninsular Malaysia and Peru.

**Table S4**. Estimated log odds of forest loss in Malaysia for areas forested in 2000.

**Table S5**. Projected carbon loss and estimated NPV of forest carbon in Peninsular Malaysia and Peru to the year 2100.

**Table S6**. Linear regression results estimating percent canopy cover change in Peru for areas forested in 2000.

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