LETTER

Using systematic conservation planning to minimize REDD+ conflict with agriculture and logging in the tropics

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Abstract

This article describes the first application of systematic conservation planning for prioritizing REDD+ (reducing emissions from deforestation and forest degradation) strategies and agricultural expansion. For a REDD+ program in Indonesian Borneo, we find that the most cost-effective way to reduce forest-based emissions by 25% is to better manage protected areas and logging concessions. A more ambitious emissions reduction target would require constraining agricultural expansion and logging, which incurs opportunity costs. We discover, however, that these impacts can be mitigated by relocating oil palm (*Elaeis guineensis*) agricultural leases to areas that store, on average, 130 tons less carbon per hectare and are 8% more productive for oil palm. This reduces the costs of meeting REDD+ targets, avoids conflict with agriculture, and has the unanticipated effect of minimizing impacts on logging. Our approach presents a transparent and defensible method for prioritizing REDD+ locations and strategies in a way that minimizes development trade-offs and promotes implementation success.

Introduction

Tropical forests are increasingly being protected, better managed, and restored under the auspices of a carbon payment mechanism termed as REDD+ (reducing emissions from deforestation and forest degradation, plus the conservation, sustainable management, and enhancement of forest carbon stocks) (Cerbu *et al*. 2011). By harnessing unprecedented funds for conservation, it is widely believed that REDD+ offers the best chance to slow tropical forest loss and secure a future for the imperiled biodiversity of this biome (Venter & Koh 2011; Strassburg *et al*. 2012).

While REDD+ could be a powerful new tool for conservation, it also has the potential to cause conflicts with other land uses and societal objectives (Ghazoul *et al*. 2010). Most significantly, by fully integrating terrestrial carbon into climate and land use policy, it could constrain forest conversion and agricultural expansion in the tropics, thereby causing an upward pressure on food prices (Wise *et al*. 2009). This situation would be further aggravated if, in an effort to reduce emissions from forest degradation, REDD+ constrains logging operations in the tropics. But could the impending conflict between REDD+, agricultural expansion, and logging be averted, or at least minimized? For this to happen, there is a need to develop transparent methods for identifying priority areas and strategies for REDD+ implementation that explicitly aim to minimize conflict with competing land uses.

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While potentially helpful for simplifying such decisions, there have been limited attempts to develop and apply quantitative decision support tools for REDD+ implementation. An exception is the use of marginal abatement cost curves (MACCs) (MacLeod *et al*. 2010). These involve plotting the cost of reducing emissions against the possible quantity reduced for major emissions sectors. However, MACCs are not a spatially explicit tool, and therefore, do not inform on where action should be taken to reduce emissions.

Independent of REDD+ developments, biodiversity conservation scientists and practitioners have recognized the complexity of making land use decisions in the context of competing objectives and have responded by developing and applying a suite of decision science tools to inform how best to protect species, ecosystems, and other biodiversity features from the threats they face (Moilanen *et al*. 2009). These tools integrate quantitative spatial data on biological, economic, and social factors to identify priority locations for cost-effective conservation intervention (Wilson *et al*. 2006). Systematic conservation planning, as it is known, has become the "best practice" among conservation practitioners (Moilanen *et al*. 2009).

Here, we develop the first framework for using systematic conservation planning for REDD+, and demonstrate how it can minimize conservation and development trade-offs. We do this in partnership with the Berau Forest Carbon Partnership (BFCP), a landscape scale, multiland use, and multistrategy REDD+ program in the Berau regency of Indonesia. We extend existing planning approaches by prioritizing not only strategies to reduce emissions, but also the optimal expansion of agriculture. As a proxy for agriculture expansion, we use oil palm (*Elaeis guineensis*) development, which not only provides the feedstock for a wide range of food products but is also a rapidly expanding industry frequently cited as a major driver of deforestation in the tropics (Koh & Wilcove 2008; Venter *et al*. 2009). We plan for the expansion of this food crop alongside forest carbon in an attempt to best align development and carbon conservation outcomes. We also quantify the trade-offs between REDD+ and logging operations. Because tropical forest regions are infamously data poor, we simulate the transferability of our planning approach to more data-poor regions and quantify how this affects our expected planning outputs and outcomes.

Methods

Berau forest carbon program

The Berau regency covers 2.2 million hectares, and with 70% natural forest cover, it is one of the few remaining areas on either Sumatra or Borneo that still contain substantial expanses of relatively undisturbed lowland dipterocarp forest (Figure 1). With a rapid increase in logging and conversion to agricultural land uses predicted for the coming decade (Harris *et al*. 2008), Berau now sits on the frontline of Borneo's deforestation frontier.

The BFCP is a multistakeholder initiative in Berau that uses an integrated landscape-scale approach to maximize the diverse benefits of reducing forest-based emissions while minimizing the impacts on other development objectives (Siswanto & Wardojo 2009). As it is the first REDD+ activity in Indonesia designed at the landscape scale, it is expected that the BFCP will serve as a testing ground and model for similar programs elsewhere in Indonesia and abroad. Five strategies for reducing emissions from Berau's forests were developed by the BFCP. The strategies involve either improving land management practices or changing land use designation, each applicable in one of the three land designation categories in Berau:

- In existing protected areas, **Strategy 1** improves land management to prevent forest carbon loss through illegal logging, forest conversion, and fire.
- In areas designated for logging (known in Indonesia as production forest, which includes pulp fiber plantations and selective logging), **Strategy 2** works with loggers to implement reduced impact logging (RIL) techniques and **Strategy 3** sets aside and protects some areas for carbon storage.
- In areas slated for agriculture, **Strategy 4** retires oil palm permits in high carbon areas and **Strategy 5** prioritizes preferred areas for the oil palm permits, using this information to facilitate oil palm "permit swaps."

Data

To provide the necessary information to prioritize among strategies and locations, we used spatial data that were collected or developed by the BFCP (Siswanto & Wardojo 2009). This included data for land use designation (Sekala 2009), forest extraction and conversion permits (Sekala 2009), mapped oil palm production potential (Smit 2009), land cover and terrestrial carbon density (Dewi *et al*. 2010), modeled future changes in carbon stocks (Dewi *et al*. 2010), and expected strategy effectiveness (Siswanto & Wardojo 2009).

In addition to these data, we extracted data from the literature to estimate the opportunity, start-up, and ongoing management costs of the five REDD+ strategies (Web Table S1). The perceived opportunity costs of forest conservation vary among stakeholders and depend on land use rights. When calculating the opportunity costs

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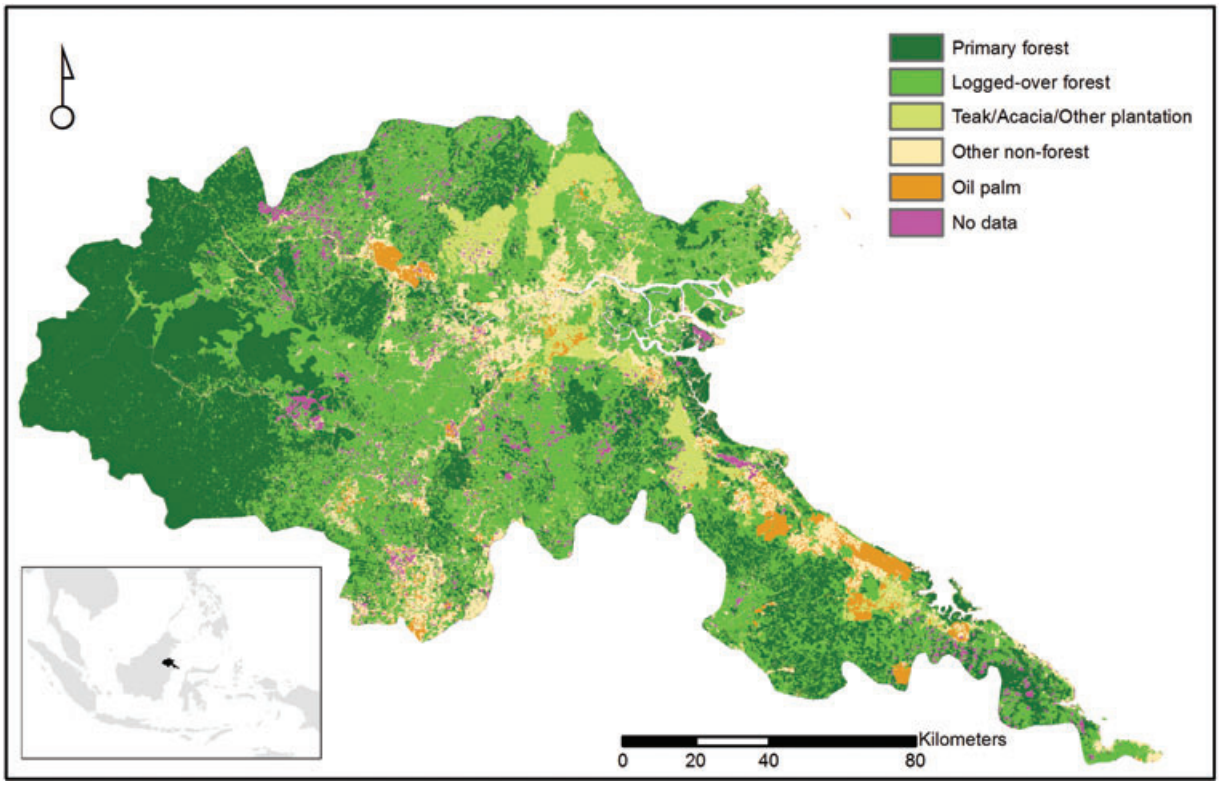


Figure 1 Map of land cover classes of Berau for 2008 (Dewi *et al.* 2010).

for lands leased for private use, we included the opportunity costs of lost employment, lost tax revenues, and lost profits to the permit holder. For lands without private use rights, we included lost employment and tax revenues that could be derived if a permit were to be granted in the future. We calculated opportunity costs as the net present value from 30 years of lost profits using a discount rate of 10.5%, one typically used by Indonesian companies (SMART-Tbk 2010). Management costs were estimated as the cost of an endowment capable of financing management into perpetuity, calculated using Indonesia's inflation rate of 3.56% and bond rate of 7.75% (www.bi.go.id). We tested the sensitivity of our results to our economic data by individually perturbing all input data in Web Table S1 up and down 50%, and by perturbing our discount, interest, and inflation rates up and down 25%.

Prioritization

We used the decision support software Marxan with Zones V2 to prioritize strategies and locations in Berau (Watts *et al*. 2009). Marxan with Zones is a multiland use planning version of Marxan, a tool widely used for systematically designing marine and terrestrial-protected areas. Its objective is to identify the combination of land use strategies and locations that minimize the costs of meeting prespecified planning targets. For a more detailed description of the Marxan with Zones software, see http://www.uq.edu.au/marxan/.

We characterize the general Marxan with Zones decision framework using Figure 2, which must then be customized for a particular decision problem. For our application, we divided Berau's land area into 28,095 hexagonal planning units (mean area 78 hectares after further subdividing based on land management boundaries), which served as our spatial units for prioritization. We identified which strategies could be assigned to each planning unit based on the list of strategies above (e.g., in areas slated for agriculture, strategies 4 and 5 could be applied). We quantified the generic costs of each strategy in each planning unit using Web Table S1. We then modified these costs based on the spatial heterogeneity in forest extent (Dewi *et al*. 2010) for logging revenues, and agricultural suitability (Smit 2009) for oil palm production values. We estimated the benefits of applying the strategies in each planning unit based on the predicted emissions that could be avoided (Dewi *et al*. 2010). When

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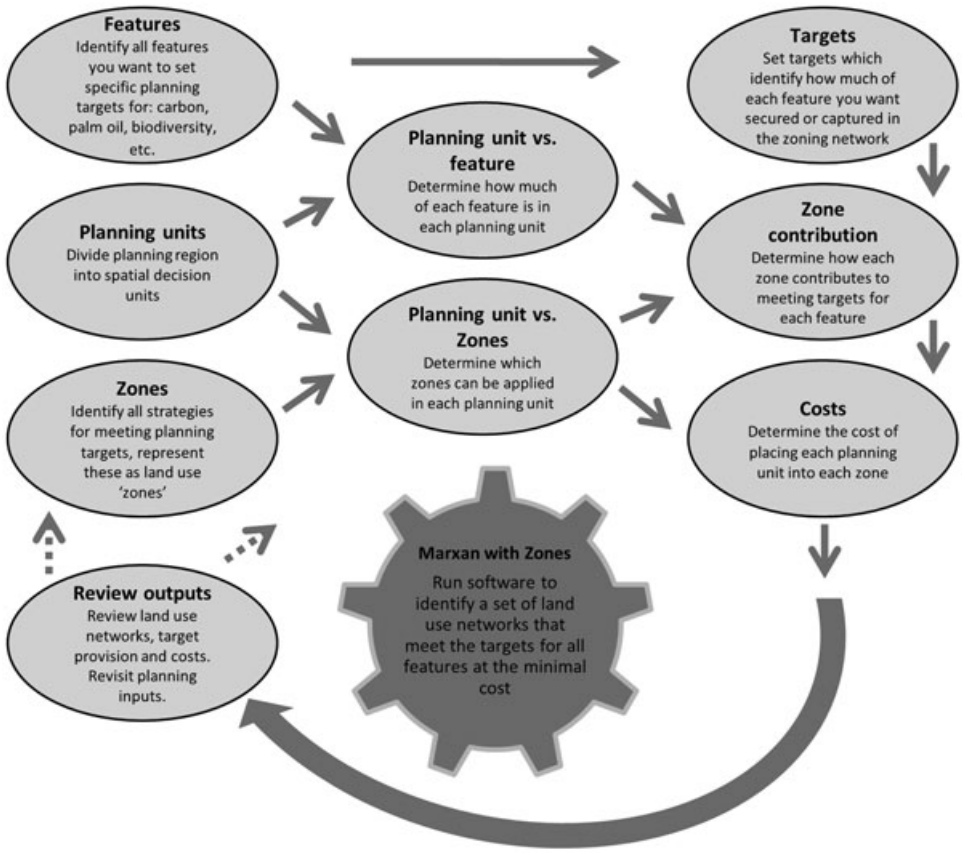


Figure 2 Graphical overview of the general Marxan with Zones planning framework.

planning for oil palm expansion (strategy 5), only oil palm permits were considered to contribute to oil palm targets.

We compared two different prioritization scenarios, and for each scenario, we used two target levels for emissions reductions, a low target equal to a 25% reduction in the next 10 years of expected emissions and a high target equal to a 50% reduction. These targets are reflective of the low and high national emissions reductions commitments made by Indonesian President Susilo Bambang Yudhoyono in Copenhagen in 2009. In the first scenario, which we dub "REDD+ focused," we only included REDD+ strategies that contribute to the conservation of forest carbon, strategies 1–4 listed above. In this scenario, we did not consider options for identifying priority areas for agricultural expansion (strategy 5), and while existing oil palm plantations could be retired, new permits could not be granted.

In the second scenario, which we term the "joint planning" scenario, we planned concurrently for REDD+ strategies and the expansion of oil palm plantations. In this scenario, we maintained the emissions reductions targets and added the additional target that planned future oil palm production was maintained at a level equal to that which would occur if all existing oil palm permits in Berau were to go ahead (128,882 productive hectares). In this scenario, if any productive oil palm permits are retired to allow the forest to be managed for carbon storage, a new oil palm permit must be granted (strategy 5) in another location to offset the lost oil palm production and ensure the oil palm target it met. The model preferentially grants new permits in areas that are simultaneously suitable for oil palm production and low in forest carbon density.

The tropics are infamously under studied, and important data on planning features and socioeconomic costs and opportunities are often lacking (Collen *et al*. 2008). Could our planning approach be transferable to regions that are more data poor than Berau? To address this question, we explored how planning outputs and outcomes would change if we only used data available for free from sources outside of the BFCP. To do this, we replaced all spatial data that had been developed specifically for the BFCP with data that are available from existing

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Table 1 Results of the area, costs, and carbon prices from prioritizing REDD+ strategies and oil palm expansion in Berau Regency, Indonesia

Strategy	Prioritized Hectares	Cost $	Cost efficiency* $·MgCO$_{2e}^{-1}$ (5 years)
Scenario 1: REDD+ strategies only, 25% of emissions			
Total prioritized	440,730	77,458,942	$4.15
1) Improve management of protected area	53,302	7,367,292	$3.53
2) Set aside logging area for carbon	46,781	49,507,626	$6.84
3) RIL	317,577	9,828,764	$1.30
4) Set aside agricultural area for carbon	23,070	10,755,260	$6.03
Scenario 2: REDD+ strategies only, 50% of emissions			
Total prioritized	725,556	410,908,244	$11.38
1) Improve management of protected area	92,838	12,831,833	$4.99
2) Set aside logging area for carbon	286,153	318,035,667	$12.13
3) RIL	284,969	8,978,932	$3.01
4) Set aside agricultural area for carbon	61,596	71,061,812	$16.45
Scenario 3: All strategies, 25% of emissions			
Total prioritized	464,320	59,940,887	$3.35
1) Improve management of protected area	45,470	6,284,739	$3.29
2) Set aside logging area for carbon	24,362	24,389,671	$6.21
3) RIL	314,408	9,662,334	$1.30
4) Set agricultural aside for carbon	49,790	19,566,927	$4.23
5) Grant new oil palm permit	30,290	37,215	na
Scenario 4: All strategies, 50% of emissions			
Total prioritized	773,468	317,573,752	$8.87
1) Improve management of protected area	82,952	11,465,404	$4.59
2) Set aside logging area for carbon	210,256	233,650,376	$10.75
3) RIL	302,417	9,480,577	$2.48
4) Set aside agricultural area for carbon	112,968	61,852,500	$7.99
5) Grant new oil palm permit	64,874	1,124,896	na

*Note: The costs of emissions reductions are relative costs and not absolute, as they do not include the benefits of reducing emissions after 5 years. The first two scenarios only include REDD+ strategies in the prioritization (i.e., planning for oil palm expansion is excluded), and include a low emissions reduction target of 25% and high target of 50%. The second two scenarios include the same target levels, but allow for oil palm expansion to be prioritized alongside emissions reductions. The results presented for each scenario are from the best solution from running Marxan with Zones 10 times for one billion iterations each time.

sources. We replaced the program's oil palm production data with a national assessment of Indonesia's land resources (RePPProt 1990), land cover and carbon content data were replaced with data from the Indonesian Ministry of Forestry's national land cover assessment (MOF 2008), and finally the modeled projections of future forest loss were replaced with existing projections from the East Kalimantan provincial scale (Harris *et al*. 2008). We consider these data to be "surrogate" values and compare the outputs and outcomes from planning with these surrogate data to those from planning with the BFCP-specific data.

Results

If our target is to reduce forest-based emissions by 25%, and we only consider strategies that contribute to the conservation of forest carbon, REDD+ strategies are needed across 20.0% of Berau's land area at an estimated once-off cost of $77 million (Table 1, scenario 1). Most of the area (84.2%) receives strategies that reduce emissions without incurring legal opportunity costs, via improving the management of protected areas and promoting RIL practices. To reduce emissions by 50%, REDD+ strategies are prioritized across 33.1% of Berau at an estimated cost of $411 million, or $11.38 per $MgCO_{2e}$ reduced (Table 1, scenario 2). At the 50% emissions reduction target, there is greater employment of strategies that stop forest exploitation and conversion compared with the 25% target scenario (47.9% and 15.8% of prioritized areas, respectively). This creates trade-offs between emissions reductions and other development objectives in Berau. In particular, it requires the canceling of 61,596 hectares of oil palm permits and the removal of 286,153 hectares of logging forest from its prescribed harvest cycle (Table 1, scenario 2). These REDD+ strategies incur opportunity costs that result in the expected cost of emissions reductions increasing almost threefold compared with the 25% emissions reductions target (Table 1).

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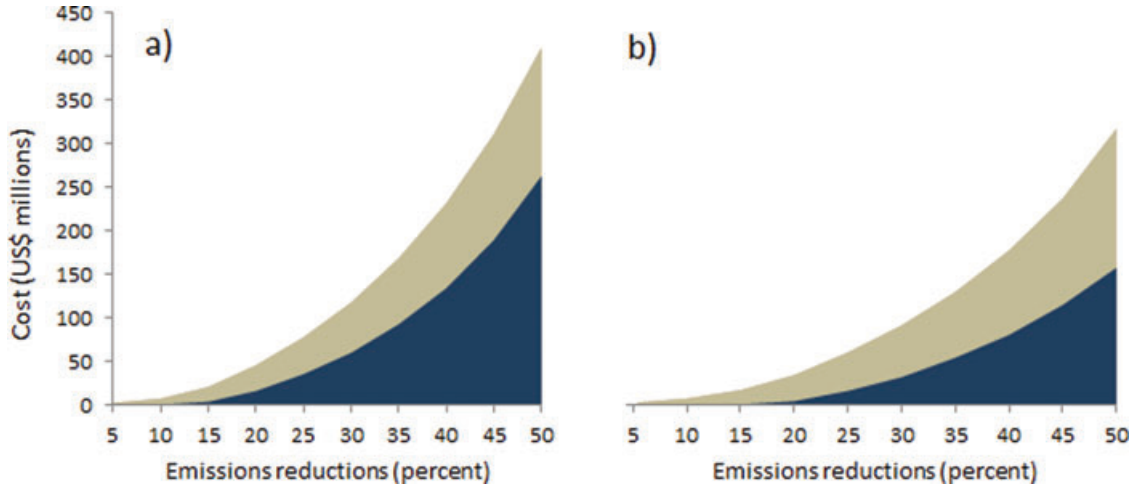


Figure 3 The total cost (green area) and the opportunity cost (blue area) of reducing emissions in the Berau regency by 50% for (a) the carbon focused and (b) joint planning scenario, which plans simultaneously for emissions reductions and oil palm expansion. The results presented are from the best solution from running Marxan with Zones 10 times for one billion iterations each time.

We discover that meeting REDD+ targets is cheaper if oil palm expansion is prioritized alongside efforts to reduce emissions, as in the joint planning scenario (Table 1). In particular, achieving both the 25% target and the 50% target becomes 23% cheaper. The greatest cost savings are from avoiding opportunity costs (which include logging and oil palm profits, tax, and employment) of the REDD+ strategies (Figure 3). When oil palm expansion is not included in the prioritization, for the 50% target, almost two-thirds of the cost of reducing emissions is from lost development opportunities (Figure 3). This falls to less than half of the total cost in the joint planning scenario.

Moreover, we find that in the joint planning scenario, land that is allocated for conversion to agriculture plays a much larger role in efforts to reduce emissions, primarily through the more widespread retiring of oil palm permits than the REDD+ strategies only scenario (Table 1). To ensure that the oil palm target is met, these retired permits are offset by the granting of new oil palm permits. We discover that the new permits are granted in areas, which store, on average, 130.7 tons less carbon per hectare and at the same time are 8.0% more productive for oil palm than the permits that are retired. REDD+ conflict with logging is also reduced in the joint planning scenario. In the case of the 50% emissions target, an extra 31,424 hectares remains open to logging compared with the REDD+ only scenario. This occurs because emission reductions can be more economically achieved through oil palm permit relocation (Table 1).

In general, using the surrogate data changed the planning outputs, which are the strategies that are prioritized and their locations (Web Table S2). This is not a great surprise given the near infinite combinations of strategies and locations for meeting planning targets. Planning outcomes, which we quantified as the expected price of emissions reductions, changed less than outputs when using the surrogate data. Using surrogate data for oil palm production or for land cover and carbon content, or even both combined, had only minor impact on the expected price of emissions reductions (Web Table S2). However, using an alternative projection of forest loss increased the cost of emissions reductions by \$14 per $MgCO_{2e}$. Perturbing our estimated costs of implementing strategies had little effect on which strategies were prioritized or where, but did have some impact on the expected cost of emissions reductions (Web Table S2). For instance, individually perturbing the cost estimates in Web Table S1 up and down by 50% changed the expected cost of emissions reduction, on average, by \$1 per $MgCO_{2e}$.

Discussion

This article presents the first spatially-explicit approach to prioritize the implementation of REDD+ strategies and locations while explicitly minimizing the costs and conflicts with other stakeholders. By applying our planning approach to a landscape-scale REDD+ program in Indonesian Borneo, we discover that when only considering REDD+ strategies, it is possible to meet a 25% emissions reduction target primarily using REDD+ strategies that improve management practices but avoid incurring opportunity costs. This highlights the substantial role that

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improving the management of protected areas and RIL practices can play in REDD+ efforts (Curran *et al*. 2004; Griscom 2009). Moreover, targeting primary forests in existing protected areas should provide substantial biodiversity co-benefits (Gibson *et al*. 2011), as should working with logging concessions, which can retain 85–100% of their biodiversity values (Putz *et al*. 2012).

At higher target levels, strategies that conflict with other land uses by actually stopping forest exploitation and conversion become more important. The conflict with oil palm agriculture can be minimized for both the low and high emissions targets, if relocation of oil palm permits is allowed and planned for concurrently with REDD+ strategies. Moreover, doing so decreases the costs of reducing emissions while simultaneously increasing the expected per hectare production values of oil palm estates. It also has the unanticipated effect of reducing REDD+ conflict with logging, as a greater share of emissions reduction can be obtained from land designated for agriculture (Table 1). These benefits of joint planning concord with the findings of Koh & Ghazoul (2010) who demonstrate that the carbon impacts of new oil palm permits can be minimized if they are directed to low carbon areas.

In order to plan most effectively for emissions reductions and oil palm expansion, it is necessary to predefine oil palm production targets. With an oil palm target set, our approach presents an efficient and transparent tool for prioritizing agricultural permits swaps at any spatial scale. This has broad and immediate applications. The Government of Indonesia has made a commitment to achieving a 26–42% reduction in forest carbon emissions while maintaining 7% annual growth in GDP. Improved land use planning could achieve much of this (Wells & Paoli 2011), and our approach could assist in identifying and negotiating the swapping and retirement of existing permits to simultaneously benefit REDD+ and agricultural production.

We discovered that using free data instead of our Berau-specific data changed which strategies and locations were prioritized, but importantly, using these data had little effect on the cost of emission reductions. This indicates that any cost savings of using our approach should still apply in cases where input data are limited. We believe that most tropical regions will have data of at least comparable quality to that of our surrogate data. For instance, forest and carbon maps exist at the global (e.g., Baccini *et al*. 2012) and regional scales (e.g., Gibbs & Brown 2007), and many regions have already performed projections of future deforestation (e.g., Laurance *et al*. 2001; Soares-Filho *et al*. 2006).

Our purpose was to demonstrate how a systematic conservation planning tool can be used to prioritize the actions of a large landscape-scale REDD+ program. Considerable scope exists for expanding on our efforts. An immediate priority should be to include strategies that lead to the enhancement of carbon stocks (Venter *et al*. 2012). Other areas for future expansion include uncertainty in data quality (Moilanen *et al*. 2006), a probabilistic treatment of the threat of forest clearance, the effects of emissions leakage (Ewers & Rodrigues 2008), and social factors in support of or opposition to REDD+ strategies (Knight *et al*. 2006).

Our study demonstrates the potential benefits of planning simultaneously for multiple objectives. Berau's forests, like all tropical forests, store vast amounts of carbon, but also house unique and endangered biodiversity, such as the endangered Bornean orangutan (*pongo pygmaeus morio*) and dozens of threatened tree species in the family dipterocarpaceae. The BFCP also aims to secure these biodiversity values (Siswanto & Wardojo 2009). Work is currently underway to incorporate biodiversity into our planning approach by identifying a comprehensive set of biodiversity features, and setting adequate targets for protecting a representative sample of these features, following the framework presented in Figure 2.

Large-scale REDD+ programs are broadly recognized as a necessary means to successfully mitigate the worst impacts of global climate change (Wise *et al*. 2009). Here, we present a transparent and defensible method for developing cost-efficient solutions for obtaining the targets set forth by these programs while promoting implementation success by reducing costs and conflict with competing land uses. Our method is designed to simplify and synthesize a very complex world, and then present this synthesis to the decision maker as a set of recommendations. As our prioritization approach will never perfectly reflect the real world, its outputs should not be interpreted as prescriptive; instead they should complement other existing forms of knowledge and extensive ground truthing, as part of the overall decision process.

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Supporting Information

Additional Supporting Information may be found in the online version of this article, including Supplementary Methods and References.

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Web Table S1: Data inputs used to calculate the start-up, opportunity, and ongoing management costs of REDD+ strategies being considered by the BFCP. All values given as a one time upfront cost in 2009 U.S.$.

Web Table S2: Change in planning outputs and outcomes from planning to reduce emissions in Berau by 50% using "surrogate" data. Surrogate data are considered as data that are available for free from sources outside of the BFCP, and they are compared with data developed specifically for the BFCP. Planning outputs are the strategies prioritized and their locations, and no change in planning outputs occurs when the same strategy and location are prioritized using the surrogate data and the true data. Outcomes are defined as the expected carbon price resulting from implementing the prioritized network of strategies, calculated as the total cost divided by the total expected emissions reductions.

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