Emissions and Potential Emissions Reductions from Logging Concessions of East Kalimantan, Indonesia

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Cover photo: Using the reduced impact monocable winch machine to pull a log from the forest at PT. Belayan River Timber concession, East Kalimantan, Indonesia. © Nurni/Jakarta Post.

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Introduction

Over 20% of natural tropical moist forests are subject to logging. Likewise, in many tropical countries over 20% of forest greenhouse gas emissions are due to logging (Griscom et. al. 2009). Demand for timber is expected to significantly increase from 2010-2015 (Kirilenko and Sedjo, 2007). If the increasing demand for timber is not met, alternative materials such as steel and cement, with higher carbon footprints, would likely substitute for that demand resulting in yet higher greenhouse gas emissions (Lippke et. al. 2004, Perez-Garcia et. al. 2005). Thus, the likely expansion of industrial logging in the tropics presents a significant challenge for efforts to mitigate climate change by Reducing Deforestation and forest Degradation (REDD).

A solution is improved methods of selective logging that can reduce emissions by 30-50% while maintaining timber production, as demonstrated by two case studies of individual logging concessions (Keller et. al. 2004, Pinard and Putz 1997). These studies offer strong results at the scale of the individual concessions where measurements were taken. However, we are not aware of prior studies that have measured these emissions reductions at larger scales as necessary to implement REDD+ for political jurisdictions.

While inexpensive medium resolution satellite data (e.g. Landsat) can be used to detect the occurrence of selective logging at political jurisdictions (Asner et. al. 2005, Souza et. al. 2005), it has not yet been demonstrated to reliably differentiate conventional vs. improved selective logging impacts. Further, we find here that to measure performance in logging emissions reductions, reliable data on the volume of timber extracted is needed, which requires independent field observations.

We report here on average emissions from conventional logging practices among logging concessions within the district of Berau, Indonesia. We also report results on potential emissions reductions by modeling the implementation of three improved logging practices. We use these results to propose a method for measuring performance in logging emissions reductions that is sensitive to background variability in timber stocking levels.

Finally, we discuss alternative practical methods for verifying emissions reductions at the scale of political jurisdictions. One approach is based on verifying practices which achieve known emissions reductions, while the other approach is based on direct monitoring of emissions reductions.

Methods

This study confronted a series of sampling challenges to address the jurisdictional scale of analysis discussed above. These challenges include:

1. The need to derive average emissions values across multiple logging concessions dispersed across a large and ecologically, topographically, edaphically, and anthropogenically complex landscape.

2. The need to independently track the emissions from different components of logging operations (i.e. hauling, skidding, felling), and to distinguish emissions levels from specific practices found in conventional vs. improved systems.
3. The need to accommodate modeling of potential emissions reductions in cases where substantially improved practices have not yet been demonstrated in the field.
4. The need to generate estimates of emissions per unit area, and per unit timber volume harvested, that do not depend upon officially reported timber volume data (of unknown accuracy), or remotely sensed data (of limited availability due to cloud cover and flight permitting challenges).

Stratified Sampling of Concessions

To address the first challenge (1), we stratified concessions across East Kalimantan, using multivariate analysis (cluster analysis, Ward's Linkage) using 10 spatial datasets representing landform (slope, elevation), soils (percent inceptisols, oxisols, ulfisols), distance from cities, and land cover classes (percent primary forest, previously disturbed forest, wetlands, and converted lands). From this analysis we derived six groups, or "clusters", of commercial logging concessions in East Kalimantan (Figure 1). Among the six groups, we selected for sampling the three groups which generate the majority of timber production in East Kalimantan:

- Group 1: remote concessions on steep slopes, predominantly primary forests on inceptisol soils.
- Group 2: somewhat remote concessions on somewhat steep slopes, predominantly on previously disturbed forests on inceptisol soils.
- Group 5: less remote concessions on less steep slopes, predominantly ulfisol soils.

Among these three groups, we randomly selected three concessions within each group for sampling (N= 9 concessions); however, random selection was constrained by the subset of those concessions we were able to access based on The Nature Conservancy's established relationships.

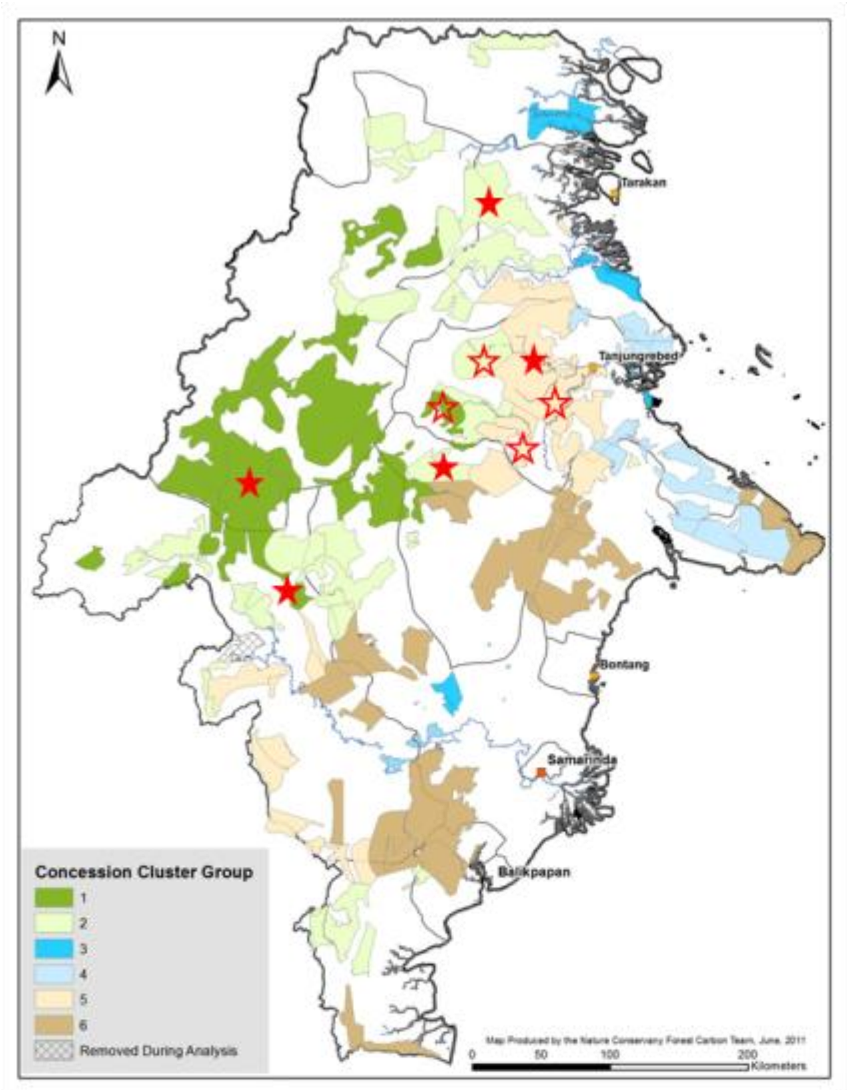


Figure 1. Distribution of 6 concession types in East Kalimantan, stratified into six groups, or "clusters", of which three (group 1, 2, and 5) were sampled. Five concessions (filled red stars) were sampled during 2009-2010, and four were sampled during 2011 (open red stars).

Field Plot Design

In order to address the remaining challenges (2,3, and 4) as outlined above, we developed three separate field sampling components to independently measure impacts from the three types of logging impacts:

i. haul roads and log landings: width (and length for landings) were systematically measured along randomly selected sections of haul road.
ii. skid trails: all skidding damage was inventoried within "skid plots" of 10 meters in length that were systematically located within randomly selected skid trail networks.
iii. tree felling: all tree felling damage was inventoried surrounding randomly selected harvest tree stumps.

The details of these field methods are provided in Appendix I (Field Methods: Carbon Emissions from Logging Concessions of East Kalimantan). Field inventory work was conducted during 2009 and 2010. Replication levels are given in Table 1.

Table 1: Area sampled and number of plots measured

Concession	Felling Gap Plots	Harvest Trees Measured	Skid Plots	Skid Network Area Sampled (ha)	Harvest Trees Tallied	Haul Road Width Measurements	Log Landings Measured
A	10	10	23	11.1	18	6	0
B	4	6	16	17.1	41	6	0
C	7	12	8	12.4	76	42	9
D	5	9	16	12.3	84	31	8
E	10	15	15	30.3	86	33	7
	36	52	78	83.1	305	118	24

Results

Hauling

Forest Carbon Density

For the purposes of calculating committed emissions per unit area of haul road and log landing, we assumed that the above- and below-ground carbon stocks in tree biomass was 288 TC/ha, the same across all logging concessions. Since we did not collect inventory data in logging blocks prior to logging activity in the five concessions described here, we derived this value as the average of three different estimates for below- and above-ground carbon stocks of "undisturbed forests" in Berau:

- Winrock: 346 TC/ha
- ICRAF: 351 TC/ha
- WHRC: 168 TC/ha

The Winrock estimate is based on a total of 82 forest inventory plots (20 m radius nested circular) located in logging blocks designated for harvest the subsequent year, within four logging concessions in Berau (Brown et. al. 2010). The ICRAF estimate (Dewi et. al. 2010) is based on a review of available literature on undisturbed forest carbon stocks in Berau, access to a Government of Indonesia forest inventory dataset, and a small number (n<5) of new plots. The WHRC estimate is based on preliminary (unpublished) results of a remote sensing analysis involving GLAS (ICESat) Lidar data, ALOS data, and MODIS data. Of course, field measurements within each concession are needed to improve our information about carbon stocks of forests cleared for haul roads and log landings.

Impacts

Haul roads and landings were, on average, responsible for clearing 9% of the total area of cutting blocks. The bulk of this area cleared, and resulting emissions, was due to haul roads (86%), and the remainder due to log landings (but note our limited number of log landing measurements in Table 1). On average, drivable road width represented only 19% of the total width of vegetation cleared for haul road corridors. The additional vegetation clearing along the road edges was apparently done to improve drying of road surfaces after rains ("daylighting"), based on communications with concession managers and TNC staff.

Average road width was significantly different among concessions (P<0.001, single factor ANOVA, Figure 2). The lowest road width was found in concession C, even though this concession had the highest mean slope.

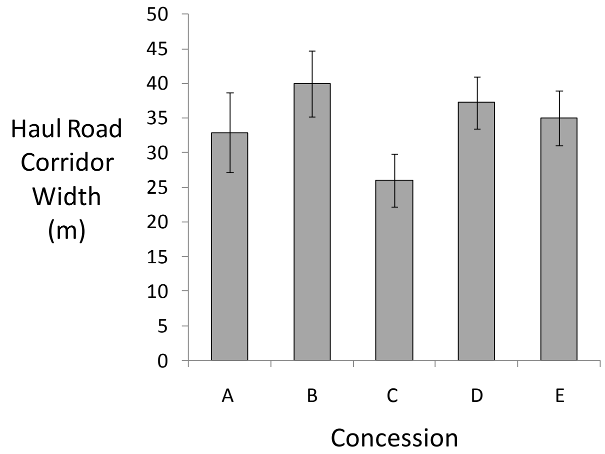


Figure 2. Total haul road width (driveable road and vegetation clearing) are presented for five concessions sampled, with error bars representing 95% confidence intervals. Larger error bars for concessions A and B are due to smaller sample size as compared with other concessions. Mean road widths from five concessions are significantly different (P<0.001, single factor ANOVA).

Potential Emissions Reductions

If average total haul road width could be restricted to 25 meters (just below that demonstrated by concession D), then total committed emissions from hauling (roads and landings) could be reduced in the average concession by 18%. A 25-meter total width restriction would allow for an average driveable road width of ~5 meters, and ~10 meter zones on either side for cleared vegetation to allow drying of road surfaces. Narrower clearance widths for road surface drying are facilitated by improved road design, including convex road surface and use of gravel on steep road sections (communications with Irianto and Putz).

We believe that it is feasible to restrict all concessions to achieve the average road width demonstrated by concession D because concession D had the highest mean slope, and we assume that higher average slopes only increase the challenge of limiting haul road impacts. It is likely that other variables affect the feasibility of reducing haul road and landing impacts, such as soil type and proximity of gravel. Some analysis of these factors may be necessary prior to establishing parameters of low emissions haul road and landing construction.

These calculations assume no change in the layout of haul roads, or in the size and location of log landings. Additional data, analysis, and engineering expertise would be necessary to assess potential additional emissions reductions through changes in haul road layout and landing design.

Skidding

Bulldozer skid trails generate less than half of the emissions generated by haul roads across the area of a cutting block. Nevertheless, bulldozer skid trails are responsible for substantial damage to trees not intended for harvest. The standard D7 bulldozer has a blade 4.2 meters wide, and the average dozer skid trail width is more than twice this blade width. As a result, bulldozer skid trails are responsible for felling the equivalent of one 40 cm dbh tree every 10 meters of skid length. However, bulldozers do avoid larger trees while skidding, to the extent that the carbon stocks of the forest area they pass through represents less than 1/3 of average forest carbon stocks. No trees over 60 cm dbh were recorded in the 86 plots (10 meters long) in which we measured skidding damage, so this appears to be the largest tree size that a bulldozer operator will fell for skid trail construction, with declining likelihood of tree avoidance with declining tree size classes below 60 cm dbh.

We found considerable variability in parameters of dozer skid trail design among the concessions, to the extent that estimated skidding emissions per ha of a logging block in the highest skidding emissions concession (D) was double that in the lowest skidding emissions concession (A). Skidding emissions are a function of the width of skid trails and the layout of skid trails (which together determine the area impacted by skid trails within a given hectare of forest), and the forest carbon stocks of the area impacted by skid trails (indicated by the column giving emissions per ha of skid trail). These factors may themselves be influenced by the density of harvest trees and slope.

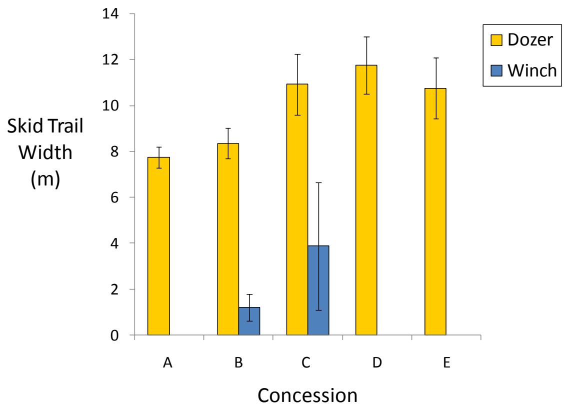
The variability in emissions between monocable winch skidding system and dozer skidding systems (an order of magnitude) is greater than the variability among dozer skidding operations. The differences presented in Figure 3 are based on a small number of skidding impact plots within limited areas employing monocable winch systems being operated on a trial basis in concessions B and C . The monocable winch systems (locally termed “pancang”) replaced bulldozers with simple winch machines: ~20 hp engines powering spools holding 100 m cables seated on metal sleds of 0.8 meters width. Anchor trees were used when winches hauled themselves into the forest, and when winches hauled trees out. Harvest logs were trimmed at the front end like pencils to reduce catching on soil, roots, or trees.

Potential Emissions Reductions by replacing bulldozers with monocable winch skidding

Average skid trail width of monocable winch systems was less than half that of dozer skidding systems. Emissions per km of skid trail was ten times lower than those found in dozer skidding systems (Figure 3). Despite the limited sample size of monocable winch sites, these differences in trail width and emissions per skidding length were highly statistically significant ($P<0.0001$) (Figure 3). Monocable systems demonstrate an even greater difference in terms of emissions per unit skid length, as compared to skid trail width, due to greater avoidance of standing trees by winch system than by bulldozers. Similar to emissions per skid length, our overall estimates of emissions per unit area from bulldozer skidding were more than an order of magnitude (10x) higher than emissions per unit area logging block from monocable winch skidding.

Full replacement of dozer trails with monocable winch skidding would achieve maximum emissions reductions; however, we have not yet sampled locations where dozer skidding was fully replaced by monocable winch skidding. The examples we have sampled to date (concessions B and C), involve the use of monocable winching to skid logs from the stump to an intermediate location, and bulldozers for skidding the remaining distance to the haul roads. Thus, we do not yet know if monocable winch systems can entirely replace dozer skidding – there may be pragmatic limitations to the size of monocable skidding networks.

Within the context of much lower monocable winch skidding emissions, we also note much higher emissions from the monocable winch system sampled in concession C than in concession B. This appeared to be due to steeper slopes in concession C. As harvest logs were winched across slopes (as opposed to directly up them) they knocked down more trees on the downslope side. Nevertheless, despite differences in terrain, the monocable winch damage remains well below damage associated with operated bulldozer skidding. From the perspective of logging impact and carbon emissions, the only potential downside of monocable winch systems is the increased potential to access steeper slope areas that might not be attempted with bulldozers. This issue could be addressed as part of effectively enforcing a maximum slope threshold for logging (to be discussed below).



a)

b)

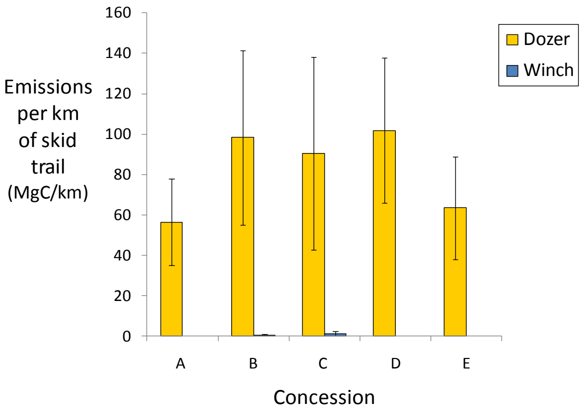


Figure 3. We detected a highly significant difference among mean concession dozer skid trail mean widths ($P<0.0001$); however, we did not detect a significant difference among mean values of concession dozer skidding emissions per km, due to high plot-level variability. Highly significant differences ($P<0.0001$) were found comparing monocable winch systems (blue columns) with dozer systems (yellow columns).

Felling

Impacts

After the transportation network (hauling, landing, and skidding) has been accounted for, the other major source of logging emissions is due to tree mortality caused by the felling of harvest trees. We assumed that all trees felled to the ground or snapped below the lowest main branch died. We assumed that all other damage classes measured (bark damage, leaning, partial damage to canopy) did not die. Overall we considered this a conservative assumption about the transfer of live biomass to dead biomass. We further separate these "felling gap" emissions into three categories: (1) "harvest tree": emissions from the remainder portion of the harvest tree left in the forest; (2) "collateral damage": emissions generated from damage to non-harvest trees as a result of the felling the harvest tree; and (3) "wood processing": emissions due to the processing and wood product waste of roundwood extracted from harvest trees.

Mean committed emissions from collateral damage due to harvest tree felling varied considerably, from 1.6 tC per harvest tree (concession A) to 2.6 tC per harvest tree (concession C); however, we did not detect a significant difference among concession averages, due to high variance within each concession (Figure 4). The concession with the lowest collateral damage level (A) was the only concession which demonstrated the practice of cutting lianas during timber cruising (months prior to felling) to reduce collateral damage resulting from interlinked canopies. However, more sampling would be necessary to conclude that liana cutting in concession A was associated with lower collateral damage impacts.

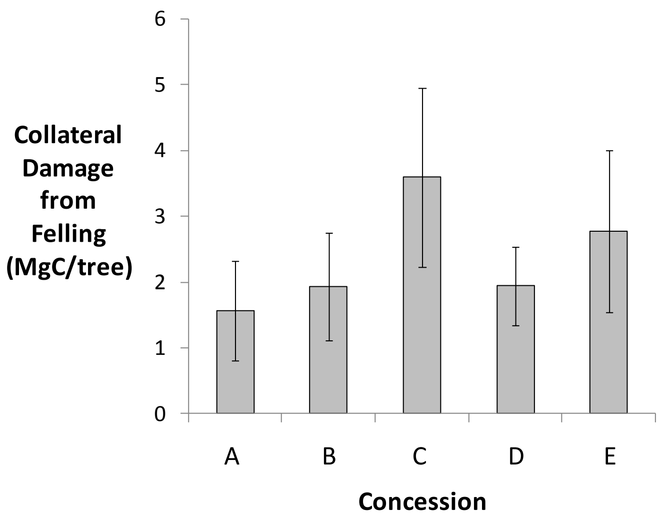


Figure 4. Committed emissions from damage to non-harvest trees during the felling of harvest trees varied considerably within and among concessions. Error bars depict 95% confidence intervals. No significant difference was found among concessions (single factor ANOVA).

More committed emissions were generated by the parts of harvest trees left in the forest than from collateral damage to other trees. Variability among concessions was high, and similar in magnitude to collateral damage. Ranking of concessions by emissions levels from the harvest tree parts left in the forest was not consistent with concessions ranking by collateral damage. For example, concession C had the highest collateral damage emissions per tree, but the lowest committed emissions from remaining harvest tree parts. Overall, concession A had the lowest emissions due to felling (including collateral damage and harvest tree remainder).

Our most striking observation related to harvest tree emissions was: 32% of felled harvest trees were left in the forest without extraction of any log section. Within sampled portions of each concessions, this value ranged from 44% (Concession D) to 20% (Concession E). In most cases, we observed that logs were left due to hollowness; however, in a minority of cases it appeared they were simply missed by skidders.

Potential Emissions Reductions

The most striking opportunity for emissions reductions is offered by the high level of unnecessary impacts associated with felling of defective trees, usually due to hollowness. Additional emissions reductions may be attributable to cutting of lianas (lower collateral damage in concession A); however, more sampling is needed to substantiate this conclusion.

Identification of Carbon Management Practices

Based on the analyses described above, and drawing on a recent report to TNC by Putz (2010), a simple set of changes in efficiency of logging operations and set asides were identified (Table 2). These practices were selected as the "low hanging fruit" to achieve emissions reductions within the context of the BFCP production forest strategy, based on the following criteria:

1) Discrete and measurable changes in conventional practice can be identified,
2) Emissions reductions associated with change can be estimated,
3) Change in practice is at the discretion of concession managers, and can feasibly be implemented across the range of landscape variables.
4) Change in practice involves no loss of associated ecological and social values held by The Conservancy and stakeholders of the BFCP.

As more information becomes available we hope to refine and expand the set of practices that meet these criteria, hereafter referred to as "carbon management practices" (CMPs)[2]. Carbon Management Practices (CMP) should be considered a subset of Reduced Impact Logging (RIL), and could be linked to certification systems (e.g. FSC); however, we point out that CMPs involve a conceptual shift from existing RIL standards (e.g. TFF) and certification systems. We construct CMPs as only those practices that have an empirical basis for their selection and definition in terms of emissions reductions. Each CMP practice is associated with a quantitative and prescriptive

[2] This name was first coined by Frances Price.

threshold, and associated emission level, that are not articulated as part of existing RIL standards. Thus, CMPs are more ambitious in the empirical basis for their selection, yet they are more limited in their scope. CMPs are clearly not designed to address the broader spectrum of social and ecological goals associated with RIL, and even more so in the case of certification systems such as FSC. Further, CMPs are likely to require more geographic specificity than existing RIL standards and certification systems because emissions associated with CMPs, and selection of CMPs, are sensitive to natural variability in landscape characteristics such as forest composition, as well as anthropogenic variables such as conventional logging practices. Notwithstanding their limited scope, we believe CMPs represent a significant advance by empirically linking an ecosystem service that has an international market value to specific practices that can be applied across jurisdictional scales and empirically verified.

Additional data collection and analyses will test assumptions we have made in developing the specific CMPs listed in Table 2 and assess additional potential CMPs. This initial set of CMPs focus on immediate reductions in transfer of live woody biomass to dead biomass associated with logging. Ideally CMPs should also include practices that address the longer term issues of improving carbon sequestration following logging operations (e.g. effective recruitment and release of tree cohorts, soil management).

Table 2. Carbon management practices (CMPs) identified for emissions reductions estimates.

Change in Practice	Quantitative Target	Comments
Reduce average haul road corridor width.	Average width of haul road corridors ≤ 25 m.	This target has been demonstrated in concession C. Target assumes no change in routing of haul roads or in landing size & frequency.
Replacement of dozer skidding with monocable winch skidding system.	Average emissions per km of skid trail ≤ 1.0 t Carbon	This target represents more than 80% reduction from current dozer impacts. It is more than double the measured average emissions per km of monocable winch skid trail. This allows for limited use of dozers for skidding between monocable winch units and haul roads. Further analysis is needed to assess the feasibility of this target.
No felling of defective trees of no commercial value.	Zero harvest trees felled with no log extracted.	This target has not been demonstrated in the field, and would require use of plunge cut by trained fellers. Some limited continued loss of whole trees will still occur under ideal operations; however, current estimate of whole tree loss is likely conservative since we have not accounted for "aborted cut" of some harvest trees that temporarily remain standing.

Emissions reductions achieved with carbon management practices

Overall Emissions Reductions

We estimate that average emissions (per ha or per m^3) would be reduced by 36% through implementation of just the three CMPs given in Table 2 (Figure 5). These emissions reductions would be achieved with no reduction in timber production, and thus no leakage (displacement of logging activity elsewhere). If improvements in set asides were also involved, emissions reductions could be brought above 50%; however, with some trade-off in loss of timber production, and thus some degree of leakage.

Total emissions per unit area for each of the five concessions were modeled assuming adoption of the three CMP logging operations practices in Table 2. Emissions estimates with CMPs were generated by calculating emissions after replacing existing measured parameters for each concession with the three quantitative efficiency target values listed in Table 6. All other unique measured parameters within each concession remained the same (e.g. felling gap emissions per harvest tree, non-defective trees harvested per unit area, volume extracted per unit area, length of skid trails per unit area, etc).

Emissions reductions breakdown: Individual CMPs

Among the three CMPs (Table 2) we estimate that the largest emissions reduction would be generated through avoidance of felling defective trees, which would decrease current felling emissions by 34% (green and grey components of columns in Figure 5). The bulk of these unnecessary emissions from felling come from the defective harvest trees left in the forest to rot (9.3 tC/ha; light green portion of columns in Fig. 5). Collateral damage to other trees from felling defective harvest trees generates an additional 3.5 tC/ha. The shift from bulldozer skidding to monocable winch skidding is expected to generate the second largest emissions reduction (8.3 tC/ha). Full adoption of monocable winch skidding (assuming a low level of bulldozer skidding as part of monocable winch systems) is expected to reduce emissions from skidding by 90%. Narrowing of haul roads corridors is expected to generate 5.2 tC/ha of emissions reductions, a 20% reduction from existing hauling impacts.

Wood processing emissions were calculated using VCS methodology (6 CP-W Wood Products V1 Nov 2010) and an assumption that that 70% of roundwood goes to wood panels and 30% to sawn wood (communication with Nawa Irianto). We assumed 100 years of decomposition time elapse. According to these calculations, 95.6% of roundwood was considered an emission.

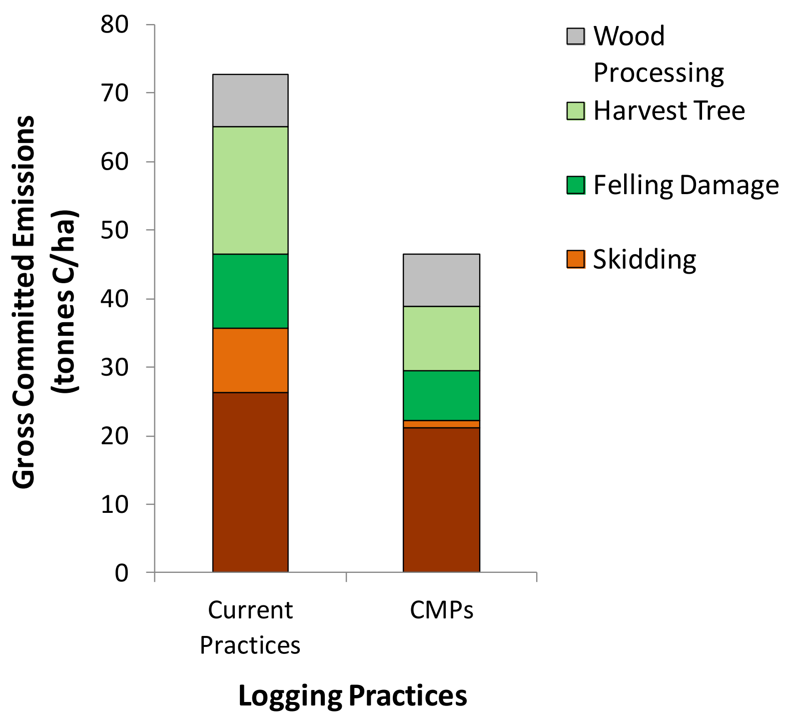


Figure 5. Grand mean emissions measured from existing practices sampled in five concessions is given in left-hand column. Predicted emissions associated with application of the three CMPs (Table 2) is given in right-hand column, and represents a 36% emission reduction from current practices. Emissions from individual components of logging operations and wood processing are differentiated in each column.

A Method for Measuring Emissions Performance of Concessionaires

Concessions demonstrate a remarkably consistent linear relationship ($r^2 = 0.92$) between emissions per hectare if CMPs were implemented, and measured volume roundwood extracted per hectare (dashed green line in Figure 6). The equation of this dashed green "CMPs" line in Figure 6 is:

$$y = 0.5x + 32.3$$

where y is tonnes C emitted per ha and x is volume roundwood per ha. The slope of the dashed green line in Figure 6 represents the following observation: *If identical logging practices are used, each additional 1 m^3 timber extracted results in additional ½ tons carbon emissions.* In addition to modeling expected emissions with application of CMPs, we can also model the expected emissions if a consistent set of "current practices" were implemented in each concession (dashed black line in Figure 6). Thus, the dashed black line, with the same slope as the CMPs line, represents a "baseline" emissions scenario that responds to varying commercial timber stocking levels.

Due to this observation that higher stocks of commercial timber are associated predictably higher emissions if practices are consistent, determining emissions per unit area is not enough to tell us about the emissions performance of a concessionaire. We also need to know volume of timber extracted per unit area.

Once we have defined a baseline that is adjusted with respect to timber volume harvested, we can measure "additional" emissions reductions achieved by individual concessionaires, as the vertical distance below the dashed black baseline in Figure 6. Furthermore, rather than setting a single target value for emissions per ha within logging concessions, it is more meaningful to establish a graduated "CMPs" target that is adjusted for timber volume harvest level. If a single target emissions level per hectare was established then a concession with low timber stocking levels would be able to claim emissions reductions relative to a concession with higher timber stocking, despite sharing the same logging practices.

We can rank the current performance of the five concessions sampled with respect to their distance from either the baseline or the CMPs line. In Figure 7 we present such a ranking, and further differentiate between "avoidable emissions" as those above the CMPs line, vs. "unavoidable emissions" as those below the CMPs line. As additional CMPs are added, or as the three proposed CMPs in Table 2 are adjusted, this determination of "avoidable" and "unavoidable" emissions would be likewise be adjusted.

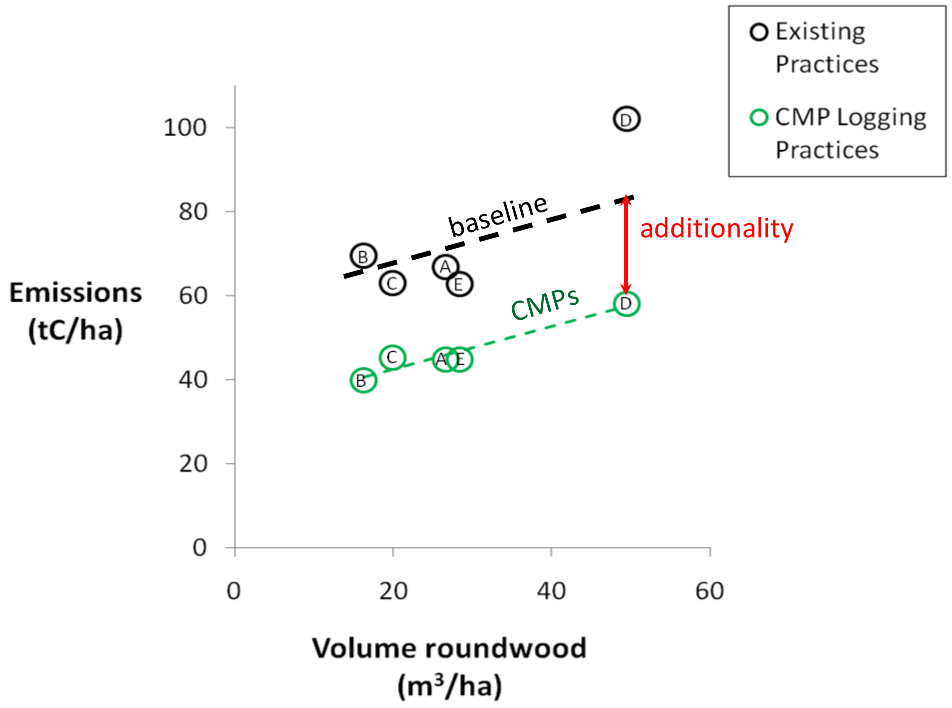


Figure 6. Average measured emissions per hectare for each concession (black circles) are plotted against volume timber (roundwood) harvested per hectare. We also plot modeled emissions in each concession if they were to adopt the three carbon management practices (CMPs) listed in Table 1 (green circles). The expected emissions under CMPs for any timber stocking level can be estimated by the green line, which is a linear regression line of the modeled outcomes. This line represents the following relationship: If CMPs are applied, each additional 1 m^3 timber extracted results in additional ½ tonne of carbon emissions.

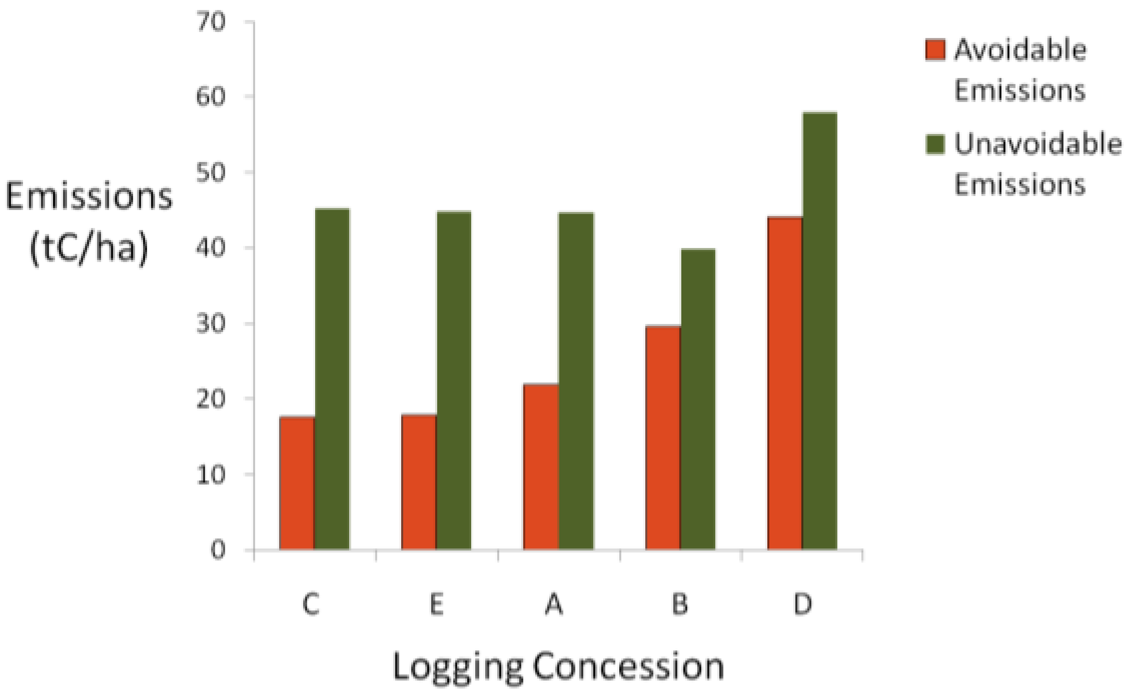


Figure 7. "Avoidable emissions" are defined as the emissions above the CMPs line in Figure 6. The remainder of actual emissions are defined as "unavoidable emissions." As additional practices are included in CMPs, a larger portion of total emissions could be identified as "avoidable." Among the five concessions sampled,

avoidable emissions range from 28-43% of total emissions. Avoidable emissions in concession C are less than half those in concession D.

Are Other Variables Needed for Assessing Performance?

While we have eliminated what we believe to be the largest confounding variable in evaluating emissions reductions performance (timber stocking level), there are other variables not at the discretion of concessionaires to change that influence emissions levels. Slope may be one such variable. We did analyze data on slope and did not identify it as a significant correlate of emissions levels; however, additional sampling may allow us to detect an effect. The distribution of timber volume among diameter size classes is another variable warranting further analysis. Tree bole volume increases exponentially with tree diameter while we have not yet detected even a linear relationship between diameter and collateral damage. Thus, logging in a forest in which timber volume occurs in a small number of large trees is expected to produce lower emissions than logging in a forest in which the same timber volume occurs in a large number of smaller trees. Following this logic, differences in legal minimum diameter limit among logging concessions may be important to take into consideration in emissions performance evaluation.

Conclusions

Just three discrete changes in logging practices would generate a substantial (36%) reduction in emissions without any decrease in timber production. These carbon management practices (CMPs), listed in order of emissions reductions achieved, are: (1) not felling defective trees, (2) adopting monocable winch skidding, and (3) narrowing haul road corridors. Additional logging practices, such as cutting of lianas, require further analysis to determine if statistically significant emissions reductions can be identified.

Monitoring logging emissions per unit area is not enough to effectively assess emissions performance, because emissions will vary depending upon timber volume harvested, even assuming the same improved practices were implemented in all concessions. Both a baseline emissions level, and a target emissions level with CMPs implementation, can be established that are adjustable with respect to varying timber harvest levels. The emissions performance of individual concessionaires can be measured with respect to these sloped threshold lines.

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