Verified Carbon Standard

VCS Module

VMD0064

PERFORMANCE METHOD FOR REDUCED IMPACT LOGGING IN TROPICAL MOIST FOREST OF THE YUCATAN PENINSULA

Version 1.0

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Sectoral Scope 14: Forestry and other land use

Version 1.0 of this module was developed by The Nature Conservancy (Peter W. Ellis and Edward A. Ellis).



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1 SOURCES

This module is based on and references VCS methodology VM0035 Methodology for Improved Forest Management through Reduced Impact Logging (RIL-C) and VMD0047 Performance Method for Reduced Impact Logging in East and North Kalimantan.

2 SUMMARY DESCRIPTION OF THE MODULE

This module is used in conjunction with VCS methodology VM0035 Methodology for Improved Forest Management through Reduced Impact Logging, specifically to account for GHG emission reductions obtained with the implementation of RIL-C practices in tropical moist forests of southern and eastern Yucatán Peninsula, Mexico. The module is also based on and adapted from VMD0047 Performance Method for Reduced Impact Logging in East and North Kalimantan. It is not valid for application with any other methodology.

All parameters established in this module are subject to periodic re-assessment. They are valid for ten years after the approval, after which they will be re-assessed, and this module updated. Note though that projects may use their validated crediting baseline and additionality benchmarks for the entire project crediting period. See the VCS Program document *Methodology Approval Process* for further information.

The inefficiencies apparent in the business-as-usual rates of logging damage occur due to a combination of factors, including:

- Poor training and adoption of directional felling practices that often result in greater number of trees being killed per felled tree;
- Not cutting lianas on trees selected for felling eight months to a year prior to harvesting;
- Skidding and yarding operations frequently conducted by timber buyers and not the community forestry enterprise (CFE) that has a greater incentive to reduce collateral skidding damage;
- Lack of supervision by a community forest technician of the logging crews and operations conducted by external buyers or contractors;
- Low adoption of lower impact skidding equipment, including modified agricultural tractors, manual extraction and long-line winches. By using longer winch cables (100 m) in place of conventional 20 m steel winch cables CFEs can access a greater number of trees at greater distances than 20 m from the skid trail that will reduce the length of

skid trail needed within the harvest area, reducing emissions during forestry operations;

- Lack of proper skid trail planning, as well as and training and supervision of skidder operators to follow optimal log extraction routes. CFEs can plan and monitor the construction of skid trails to improve efficiency. Evenly spaced, consistently branching skid trail networks with few loops and parallel paths decreases skidding damage and emissions; and
- Setting up more log landings than needed due to lack of proper harvest operations planning.

3 DEFINITIONS

Community Forestry Enterprise (CFE)
Market-oriented enterprises owned and managed by communities for the production of timber and non-timber forest products.

Diameter at Breast Height (DBH)
Diameter of a tree taken at the standard height of 1.3 m above ground level.

Ejido
Communal land tenure system institutionalized after the Mexican Revolution in which agrarian or rural communities control the use and management of land for agricultural and forestry production.

Felled Tree
A tree specifically cut for harvest (i.e., not cut or killed due to skidding operations or collaterally killed from felling nearby harvest trees). Felled trees are indicated by the presence of a chainsaw-cut stump of commercial size.

Forest Management Plant (FMP)
A site-specific plan that guides the management of a forest for timber and related resources (e.g. water, wildlife, etc.) on land where forestry- or conservation-related activities and practices are the primary use of the land.

Harvest Tree
A felled tree that has had a portion of its trunk extracted from the felling site.

Harvest Area (A_t)
The forest area in year that is accessed by haul roads and skidding equipment (parameter A_t referenced in *VM0035 Methodology for Improved Forest Management through Reduced Impact Logging*). In the case of the tropical moist forest in the Yucatan Peninsula:

- In the case of conventional winching as observed in the project area, the harvest area is defined as all areas within 18.2 m of a skid trail centerline or within a haul road corridor (authors' unpublished data).
- In the case of improved winching with longer cables, the harvest area is defined as all areas within 100 m of a skid trail centerline (Griscom et al. 2014).

Improved Winch Skidding Systems
Use of longer winch cables > 10 m installed in skidders or modified agricultural tractors.

Killed Tree
A tree that has fallen to the ground, has been uprooted, or has had its trunk snapped below the first branch as a result of logging activities. Leaning trees, trees with damaged bark, or trees with damaged canopy are not considered killed because no good evidence exists to demonstrate that logging damage eventually kills these trees.

Logging Landscape
The geography, class of actors/sector, major logging system (e.g., selective harvest) and timeframe within which the relationships of the impact parameter (with emission reductions) are applicable, and which is defined in the corresponding region-specific RIL-C performance method module.

Major Branch
A branch, the diameter of which is at least one third of the diameter of the main stem it emerges from.

Reduced Impact Logging for Climate (RIL-C)
Application of timber harvesting guidelines designed to minimize the deleterious environmental impacts of tree felling, yarding, and hauling, specifically to achieve climate mitigation.

Sub-Block
A smaller area for sampling within the harvest area, delimited to monitor skidding impacts.

4 APPLICABILITY CONDITIONS

This module is applicable under the following conditions:

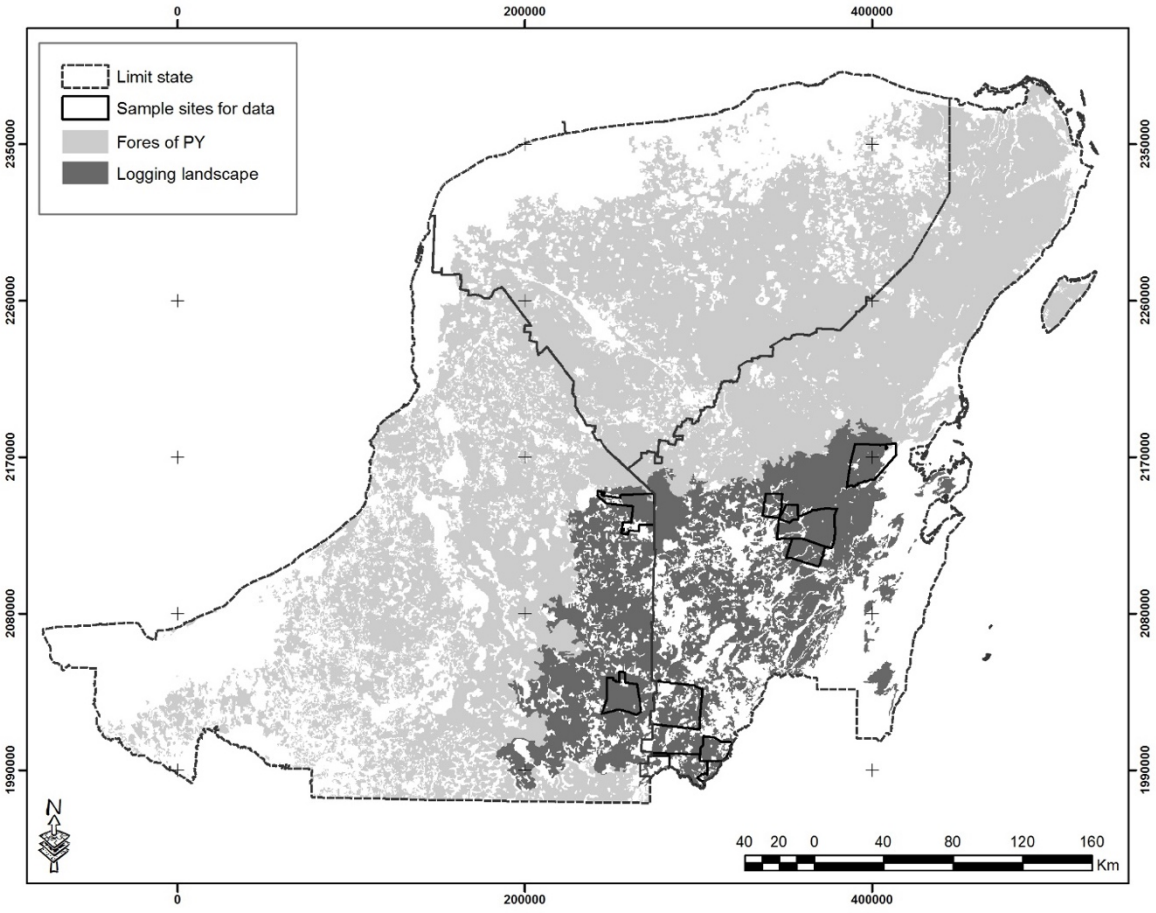
1) Project must be located in the logging landscape in the Southern and Eastern Yucatan peninsula shown in Figure 1 (Ellis et al. 2019).
2) The project area must be ejido land (communal forests) where logging is done by a CFE with proper government authorization and a current approved FMP.

3) Logging must be done based on a selective silvicultural system with cutting diameter limits for high-value timber (e.g., mahogany) and common tropical or lesser-value species specified in the FMP.

4) The CFE must be actively pursuing and complying with their FMP as well as relevant Mexican federal and state regulations and must not have any current sanctions against them related to their forest management operations.

5) Projects are not eligible for crediting during years when felled tree density, FTD_t, is below 5 trees/ha, in which it is assumed that a deliberate reduction in harvest level has occurred.

Figure 1: Southern and eastern Yucatan Peninsula logging landscape withing which parameters set out in this module are applicable (depicted in dark grey)



5 PROCEDURES

5.1 Derivation of Impact Parameter Crediting Baselines and Additionality Benchmarks

Crediting baselines and additionality benchmarks were established for each of the two impact parameters identified: FELL and SKID (Tables 2 and 3 below).

All data presented are based on field measurements reported in Ellis et al. (2019). Field work was conducted January-April 2014 and March-November 2015 in 10 CFEs selected from 33 CFEs conducting timber harvests in that time frame, all located within the specified logging landscape. Seven CFEs were randomly selected, 2 were included because of their certification with Forest Stewardship Council (FSC) and an additional ejido was a previous project pilot site.

The sample of 10 CFEs was stratified to include:

- 3 large CFEs (with harvest areas larger than 500 ha) with well-developed improved logging practices, 2 of which are FSC-certified
- 2 large CFEs (with harvest areas larger than 500 ha) with poorly developed logging practices
- 2 small CFEs (with harvest areas smaller than 500 ha) with well-developed improved logging practices
- 3 small CFEs (with harvest areas smaller than 500 ha) with poorly developed logging practices

Improved logging practices were identified in a previous study of Improved Forest Management in the Yucatan Peninsula, which reviewed the Forest Management Plans for most CFEs (Ellis et al. 2014). In this manner, impact parameters (FELL, and SKID) and benchmarks associated with different available technologies and current practices (e.g., directional felling, skid trail planning, improved winching, modified tractors) represent the full range of variation in the project area with a slight conservative bias towards CFEs with more well-developed improved logging practices. For example, while FSC certified CFEs represented 27% of our sample area (36% of sample harvest volumes), they only occupy 2% of the area in the logging landscape (15-20% of volume).

The methodology used for this study is based upon P. Ellis (2014) *Field Methods: Carbon Emissions from Logging Operations in the Yucatan Peninsula, Mexico* and Griscom et al. (2014).

In all 10 CFEs, the 2014 harvest area was sampled for harvest impacts on biomass from felling, skidding and hauling.

Based on the results of Ellis et al. (2019) and a Stakeholder Workshop (March 4, 2016) in Quintana Roo, Mexico (Appendix 1) the following RIL-C practices were identified with potential to reduce carbon emissions from timber harvesting operations within the logging landscape:

1. Improved skid trail planning;
2. Secondary harvest of branches and other wood waste;
3. Longer winch cables and improved drag path cuts;
4. "Bosquete" harvesting (i.e., group selection or small patch cuts);
5. Directional felling;
6. Improved skidding equipment (e.g., modified agricultural tractor);
7. Intensification of harvesting; and
8. Subdivision of harvest area into smaller sub blocks or basic management units (i.e., 25 to 100 ha).

Subsequently, based on the identified RIL-C practices, a group of stakeholders and local experts convened to evaluate and select suitable impact parameters that resulted from 4 practices with clear and measurable emissions reductions:

1. Improved skidding equipment (SKID);
2. Improved skid trail planning (SKID);
3. Improved winching (SKID); and
4. Directional felling (FELL).

All crediting baselines were set at the grand mean value for each impact parameter, averaged down to nearest whole number. All additionality benchmarks were set at the first quartile value for each impact parameter, averaged down to the nearest whole number. The values for all impact parameter benchmarks, and the basis for their derivation, are given in Table 2.

5.1.1 Equations for Quantifying GHG Emission Reductions

Equations are given in Sections 5.1.1 - 5.1.3 for calculating emission reductions as a function of each of the two impact parameters mentioned above and listed in Tables 2 and 3.

5.1.1.1 Procedures for Including Deductions in the Calculations of Emission Reductions as a Function of Uncertainty

Calculations of emission reductions for all impact parameters incorporate deductions for uncertainty. Deductions were made by assigning values at the bottom end of the 95% confidence intervals for key input variables, including CDB_{FELL_AGC}, CDB_{FELL_BGB}, CDB_{SKID_AGC}, and CDB_{SKID_BGB}, used in calculating the relationship between impact parameters and emissions.

In addition to these deductions, the baselines for each impact parameter are conservative because, by including a higher proportion of FSC-certified concessions in the sample than

exists in the population, a conservative bias was incorporated in the selection of the nine logging concessions sampled for source data as described above.

5.1.1.2 Procedures for Establishing a Performance Benchmark Based Upon Available Technologies and/or Current Practices, and Trends, within the Sector

Since the early 1990s, CFEs in the region have developed and adopted a variety of improved logging practices including directional felling, improved forest inventories, harvest planning and enrichment planting with high value species. Several CFEs within the logging landscape were the first forestry operations to get certified by the Forest Stewardship Council (FSC). Today, the CFEs practicing forest management represent a broad spectrum of improved forest management adoption. CFEs can range from large forestry operations in which they are directly involved in harvesting, some even processing sawnwood, to CFEs having very small forestry operations, with limited development and no involvement in harvesting timber. Currently there are two FSC certified CFEs within the logging landscape, both of which were intentionally included in our sample. Presently, only two CFEs are applying improved or alternative skidding technology such as modified agricultural tractors to extract felled trees. The biased inclusion of FSC certified concessions in the sample was intentional, and results in a conservative baseline, as explained above.

Table 2: Procedure to determine Impact Parameters

Harvest activity category	Emissions Category	Impact Parameter	Procedure to Confirm
Felling: Includes improvements in directional felling.	Emissions from killed trees during felling.	FELL: Average number of trees > 10 cm DBH killed per felled tree	Visual assessments of killed trees in felling gap.
Skidding: Pre-harvest inventory skid trail planning and/or improved long-line winching and/or use of modified tractor	Emissions from mortality resulting from skidding damage.	SKID: Average number trees > 10 cm DBH killed by skidding per harvest area (ha)	GPS mapping sampled skid trails and tally of trees killed.

Table 3: Calculation of baseline and additionality benchmarks

Ejido Code	FELL: Average number of trees > 10 cm DBH killed per felled tree	SKID: Average number of trees > 10 cm DBH killed per harvest area A_t (ha)
1	1.28	37.80
2	2.11	20.50
3	1.90	24.66
4	2.36	33.03
5	3.33	39.69
6	2.68	27.31
7	2.67	38.29
8	2.95	11.61
9	2.05	4.50
Crediting Baseline (mean)	2.38	26.38
Additionality Benchmark (Q1)	2.05	20.50

5.1.2 Felling Impact Parameter (FELL): Average Number of Trees > 10 cm DBH Killed per Felled Tree

5.1.2.1 Additionality and Crediting Baseline

Felling Impact Parameter (FELL) is the number of trees above 10 cm DBH that are killed from felling. The crediting baseline for FELL is set at 2.38 killed trees per felled tree, the grand mean whole number value across all nine CFEs sampled.

The additionality benchmark for FELL is set at 2.05 killed trees per harvest tree, which is the first quartile value among the nine ejido mean values. Based on field measurements and expert consultation, this is considered a feasible yet ambitious threshold.

5.1.2.2 Quantification of GHG Emission Reductions

Reductions in the FELL impact parameter below the crediting baseline results in avoided CO2 emissions, calculated using the following equations (equations 1 and 2 are f_{AGC} ($FELL_t$) and fBGB ($FELL_t$) as referenced in VM0035):

$$ER_{FELL,AGC,t} = (2.38 - FELL_t) \times CDB_{FELL_AGC} \times FTD_t \times R \quad (1)$$

$$ER_{FELL,BGB,t} = (2.38 - FELL_t) \times CDB_{FELL_BGB} \times FTD_t \times R \quad (2)$$

Where:

$ER_{FELL_AGC,t}$	=	Emission reductions from aboveground carbon due to reductions in *FELL* below crediting baseline within the annual harvest area at time t; tCO_2e/ha
$ER_{FELL_BGB,t}$	=	Emission reductions from belowground carbon due to reductions in *FELL* below crediting baseline within the annual harvest area at time t; tCO_2e/ha
$FELL_t$	=	Measured felling impact parameter at time t; average number of killed trees per felled tree
2.38	=	Crediting baseline; number of killed trees per felled tree
CDB_{FELL_AGC}	=	Aboveground collateral damage biomass carbon of killed trees resulting from felling; fixed default value of 0.054 tC/killed tree
CDB_{FELL_BGB}	=	Belowground collateral damage biomass carbon of killed trees resulting from felling; fixed default value of 0.013 tC/killed tree
FTD_t	=	Felled tree density at time t; trees/ha
R	=	Ratio of CO_2 to C molecular weight; fixed default value of 44/12

Conservative default values were calculated for collateral damage biomass carbon (*CDB*) at the bottom end of the 95% confidence intervals based on emissions per harvest tree for each ejido.

5.1.3 Skidding Impact Parameter (SKID): Number of Trees > 10 cm DBH Killed per harvest area

5.1.3.1 Additionality and Crediting Baseline

The skidding impact parameter (SKID) is the number of trees greater than 10.0 cm DBH killed by skidding operations per hectare of harvest area.

The baseline for SKID was set at 26.4 killed trees/ha representing the grand mean value across all CFEs sampled during the TNC RIL-C project. The additionality benchmark for SKID was set at 20.5, which is the first quartile value among the nine ejido mean values.

5.1.3.2 Quantification of GHG Emission Reductions

Reductions in the SKID impact parameter below the crediting baseline results in avoided CO_2 emissions, calculated using the following equations:

$$ER_{SKID,AGC,t} = (26.38 - SKID_t) \times CDB_{SKID_AGC} \times R \quad (3)$$

$$ER_{SKID,BGB,t} = (26.38 - SKID_t) \times CDB_{SKID_BGB} \times R \quad (4)$$

Where:

$ER_{SKID_AGC,t}$	=	Emission reductions from aboveground carbon due to reductions in SKID below crediting baseline at time t; tCO_2e/ha
$ER_{SKID_BGB,t}$	=	Emission reductions from belowground carbon due to reductions in SKID below crediting baseline at time t; tCO_2e/ha
26.38	=	Crediting baseline value for mean number of trees > 10 cm DBH killed per ha; trees/ha
$SKID_t$	=	Measured value for skidding impact parameter at time t - the mean number of trees > 10 cm DBH killed by skidding per ha; trees/ha
CDB_{SKID_AGC}	=	Aboveground collateral damage biomass carbon of killed trees resulting from skidding; fixed default value of 0.033 tC/killed tree
CDB_{SKID_BGB}	=	Belowground collateral damage biomass carbon of killed trees resulting from skidding; fixed default value of 0.010 tC/killed tree
R	=	Ratio of CO_2 to C molecular weight; fixed default value of 44/12

Conservative default values were calculated for collateral damage biomass carbon (CDB) at the bottom end of the 95% confidence intervals based on emissions per damage tree for each ejido.

5.2 Procedures to Monitor Impact Parameters

The purpose of monitoring is to generate field measurements after each harvest from which emission reductions can be estimated. Thus, following completion of each harvest, all impact parameters from all logging emission source categories considered (felling and skidding) shall be sampled in the field and estimated according to the procedures specified below.

Monitoring RIL-C impact parameters in the logging landscape of the Yucatan Peninsula involves accessing the annual harvest area, georeferencing and mapping skid trails, sampling skid trails for number of killed trees, and sampling felled trees for collateral damage. A summary of required sampling intensity is given in Table 4 below.

Throughout the project crediting period, monitoring shall be conducted within two years after each harvest.

Table 4: Calculation of baseline and additionality benchmarks

IP Name	IP Measurement	Sample Size Requirement
FELL	Average number of killed trees per felled tree	≥ 100 felled trees in at least 2 sub-blocks of the harvest areas.
FTD	Felled tree density (trees/ha)	Complete census of all sampled sub-blocks of the harvest area

SKID: $SKID_{dam}$	Calculated from measured parameters: L_{SKID}: length of sampled skid trail networks in harvest area (m) $Tree_{dam}$: number of killed trees > 10 cm DBH per sampled skid trail in harvest area (number)	Tally of all trees ≥ 10 cm DBH killed along skid trail lengths in sampled sub-blocks totaling ≥ 5.0 km.
SKID: $SKID_{dens}$	Calculated from measured parameters: L_{SKID}: length of all skid trail network in sampled sub-blocks in harvest area A_{SKID}: area corresponding to skid trail network in sampled sub-blocks in harvest area	Complete census of skid trail networks in sampled sub-blocks totaling ≥ 5.0 km.

5.2.1 Procedures to Monitor Impact Parameters

Parameter $FELL_t$, average number of trees > 10 cm DBH killed per felled tree in harvest area from year t, is monitored via a complete census, of ≥ 100 felled trees within at least 2 sub-blocks in the harvest area.

Felled tree density (FTD) is measured via a complete census (100% sample) of the harvest area A_t.

5.2.2 Procedures to Monitor Impact Parameters

Parameter $SKID_t$, average number of trees greater than or equal to 10 cm DBH that have been killed due to skidding activity per hectare in the harvest area from year t, is equal to the product of the two following monitored parameters:

$SKID_{dens,t}$	=	Average length of skid trails per hectare in harvest area from year t (m/ha)
$SKID_{dam,t}$	=	Average number of trees > 10 cm DBH killed trees per m skid trail in harvest area from year t (number/m)

Parameter $SKID_{dens}$ is calculated by dividing the total length of all sampled skid trails within the sampled sub-blocks ($L_{SKID,i,t}$) by the total area of sampled sub-blocks ($A_{SKIDi,t}$).

$$SKID_{dens,t} = \sum_{i=1}^{n} L_{SKID,i,t} \div \sum_{i=1}^{n} A_{SKID,i,t} \quad (5)$$

Where:

$SKID_{dens,t}$	=	Average meters length of skid trails per hectare in harvest area from year t (m/ha)
$L_{SKIDi,t}$	=	Length of all skid trail network in sampled sub-blocks in harvest area from year t (m)
$A_{SKIDi,t}$	=	Length of all skid trail network in sampled sub-blocks in harvest area from year t (m)

Record the number of killed trees ≥ 10 cm DBH along sampled skid trail networks. Note that any felled harvest trees or killed trees due to collateral damage from the felling of harvest trees encountered in the immediate skid trail are not included in the counts. Note that any tree ≥ 10 cm DBH that was indirectly killed due to skidding activity is included in the counts (e.g., a tree ≥ 10 cm DBH that was knocked down by a tree that was knocked down by a forestry tractor).

Average number of trees > 10 cm DBH killed per m skid trail in annual harvest area from year t, $SKID_{dam,t}$, is calculated weighting by skid trail network length.

$$SKID_{dam,t} = \sum_{i=1}^{n} \left(\frac{L_{SKIDi,t}}{\sum_{i=1}^{n} L_{SKIDi,t}} \right) \times \left(Tree_{dam,i,t} \div L_{SKIDi,t} \right) \quad (6)$$

Where:

$SKID_{dam,t}$	=	Average number of trees > 10 cm DBH killed per m skid trail in annual harvest area from year t (number/m)
$L_{SKIDi,t}$	=	Length of all skid trail network in sampled sub-blocks in harvest area from year t (m)
$Tree_{dam,i,t}$	=	Number of killed trees ≥ 10 cm DBH per sampled skid trail i in harvest area from year t (number)

The two component parameters are combined in the equation below to produce parameter $SKID_t$.

$$SKID_t = SKID_{dens,t} \times SKID_{dam,t} \quad (7)$$

Where:

$SKID_{dam,t}$	=	Average number of trees ≥ 10 cm DBH killed in skid trails per ha in harvest area from year *t* (number/ha)

$L_{SKIDi,t}$ = Average meters length of skid trails per hectare in harvest area from year *t* (m/ha)

$Tree_{dam,i,t}$ = Average number of trees ≥ 10 cm DBH killed per m skid trail in harvest area from year *t* (number/m)

6 DATA AND PARAMETERES

6.1 Data and Parameters Available at Validation

Data / Parameter	R
Data unit	Dimensionless
Description	Ratio of CO_2 to C molecular weight
Equations	1, 2, 3 and 4
Source of data	Periodic table
Value applied	44/12
Justification of choice of data or description of measurement methods and procedures applied	Based on fixed ratio of molecular weight
Purpose of Data	Calculation of emission reductions
Comments	N/A

Data / Parameter	CDB_{FELL_AGC}
Data unit	tC/killed tree
Description	Collateral damage aboveground biomass carbon due to felling
Equations	1
Source of data	Either a fixed default value of 0.054 or calculated.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The conservative default value was calculated for collateral damage biomass carbon (CDB) as the bottom end of the 95% confidence intervals based on measurements in Ellis et al. 2019. Project area-specific estimates for CDB shall be derived from the bottom end of the 95% confidence intervals of measured

	stocking levels if 95% confidence intervals represent ± ≥15% of the mean - otherwise the mean estimate can be used.
Purpose of Data	Calculation of emission reductions
Comments	N/A

Data / Parameter	CDB_{FELL_BGB}
Data unit	tC/killed tree
Description	Collateral damage belowground biomass carbon due to felling
Equations	2
Source of data	Either a fixed default value of 0.013 or calculated.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The conservative default value was calculated for collateral damage biomass carbon (CDB) as the bottom end of the 95% confidence intervals based on measurements in Ellis et al. 2019. Project area-specific estimates for CDB shall be derived from the bottom end of the 95% confidence intervals of measured stocking levels if 95% confidence intervals represent ± ≥15% of the mean - otherwise the mean estimate can be used.
Purpose of Data	Calculation of emission reductions
Comments	N/A

Data / Parameter	CDB_{SKID_AGC}
Data unit	tC/killed tree
Description	Collateral damage aboveground biomass carbon due to skidding
Equations	3
Source of data	Either a fixed default value of 0.033 or calculated.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The conservative default value was calculated for collateral damage biomass carbon (CDB) as the bottom end of the 95% confidence intervals based on measurements in Ellis et al. 2019. Project area-specific estimates for CDB shall be derived from the bottom end of the 95% confidence intervals of measured stocking levels if 95% confidence intervals represent ± ≥15% of the mean - otherwise the mean estimate can be used.
Purpose of Data	Calculation of emission reductions

Comments	N/A

Data / Parameter	CDB_{SKID_BGB}
Data unit	tC/killed tree
Description	Collateral damage belowground biomass carbon due to skidding
Equations	4
Source of data	Either a fixed default value of 0.010 or calculated.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The conservative default value was calculated for collateral damage biomass carbon (CDB) as the bottom end of the 95% confidence intervals based on measurements in Ellis et al. 2019. Project area-specific estimates for CDB shall be derived from the bottom end of the 95% confidence intervals of measured stocking levels if 95% confidence intervals represent ± ≥15% of the mean - otherwise the mean estimate can be used.
Purpose of Data	Calculation of emission reductions
Comments	N/A

6.2 Data and Parameters Monitored

Data / Parameter:	$FELL_t$
Data unit:	number killed trees/felled tree
Description:	Felling impact for application in the Yucatan Peninsula: average number of killed trees per felled tree in annual harvest area from year t
Equations **Source of data:**	1, 2 Field surveys
Description of measurement methods and procedures to be applied:	A tally of all killed trees per felled tree sampled is kept throughout the sample, from which $FELL_t$ at time t is calculated. Tallies are conducted in all, or a subsample of, the same skid trail networks sampled for $L_{SKIDi,t}$ and $A_{SKIDi,t}$. A complete tally shall be completed for each of the skid trail networks where a tally of felled trees is begun.
Frequency of monitoring/recording:	Within two years after each annual harvest.

QA/QC procedures to be applied:	Standard quality control / quality assurance procedures for forest inventory including field data collection and data management shall be applied. Sampling plan and standard operating procedures (SOPs) for field measurements must be documented. Procedures to randomize selection of skid trail networks for sampling shall be documented. Throughout field measurement events, an opportunistic sample of ~10% of sampled felled trees shall be re-measured to assess measurement error – average difference in % felled trees abandoned between re-measurements and original measurements must not exceed 10% of $FELL_t$. Re-measurement for this purpose shall be done by different field personnel.
Purpose of data:	Calculation of emission reductions
Comments:	Felled trees tallied within a skid trail network are all felled trees visible from areas accessed by skidding machinery (≤ 18.2 m from skid trails, ≤ 100 m from long-line cable winch anchor points) in skid trail networks sampled. Pacing of these distances is sufficient for establishing the boundaries of the search area.

Data / Parameter:	$L_{SKIDi,t}$
Data unit:	m
Description:	Length of all skid trail network in sampled sub-blocks in harvest area from year t
Equations	5, 6
Source of data:	Field surveys
Description of measurement methods and procedures to be applied:	Measured directly by complete mapping. Also note that this parameter represents skid trail length in the horizontal plane (i.e., skid trail length shall be corrected for slope).
Frequency of monitoring/recording:	Within two years after each annual harvest
QA/QC procedures to be applied:	Standard quality control / quality assurance procedures for forest inventory including field data collection and data management shall be applied. Sampling plan and standard operating procedures (SOPs) for field measurements must be documented and specify how field use of GPS units will avoid inclusion of spurious tracks by field crews unrelated to skid trail centerlines. GPS accuracy during field measurements shall be recorded and shall be less than 10 m. GIS smoothing procedures should be

	employed to eliminate GPS tracking error (which can cause raw GPS track to show small scale jagged lines which do not reflect actual skid trail centerlines).
Purpose of data:	Calculation of emission reductions
Comments:	N/A

Data / Parameter:	$A_{SKIDi,t}$
Data unit:	Ha
Description:	Area corresponding to skid trail network in sampled sub-blocks in annual harvest area from year t
Equations	5, 6
Source of data:	GIS analysis
Description of measurement methods and procedures to be applied:	The area corresponding to the skid trail network is estimated by applying a buffer 18.2 m either side of the vector map of the skid trail network using GIS (or 100 m from long line winch system skidding). The outer boundary of the polygon formed by the buffered skid trail network is the area corresponding to that skid trail network. Any areas outside the boundary of the annual harvest area from year t shall be excluded.
Frequency of monitoring/recording:	Within two years after each annual harvest
QA/QC procedures to be applied:	All GIS procedures applied to generate $A_{SKIDi,t}$ shall be documented. Any imagery or GIS datasets used shall be geo-registered referencing corner points, clear landmarks or other intersection points. Area limits of $A_{SKIDi,t}$ will be constrained by the haul road at the base of the skid trail network, the boundaries of the annual harvest area, and any areas within the harvest area that are not accessed, and thus excluded from A_t.
Purpose of data:	Calculation of emission reductions
Comments:	N/A

Data / Parameter:	$Tree_{dam}$
Data unit:	Number
Description:	Number of killed trees ≥ 10 cm DBH killed by skidding tallied along skid trail network i in annual harvest area from year t
Equations	6
Source of data:	Field surveys along sampled skid trail networks

Description of measurement methods and procedures to be applied:	Killed trees are censused along the same skid trail networks measured to assess skid trail length. All killed trees ≥ 10 cm DBH within sampled skid trail networks (≥ 5 km of skid trail length) are tallied (counted). Killed trees are trees that have fallen to the ground, been uprooted or with trunk snapped below the first branch. Note that any felled harvest trees encountered in the immediate skid trail are not included in the counts.
Frequency of monitoring/recording:	Within two years after each annual harvest
QA/QC procedures to be applied:	Standard quality control / quality assurance procedures for forest inventory including field data collection and data management shall be applied. Sampling plan and standard operating procedures (SOPs) for field measurements shall be documented. Procedure to randomize selection of skid trail starts shall be documented. During field measurement, one sampled skid trail network will be selected for re-measurement to assess measurement error. The $Skid_{dam,t}$ parameter, calculated independently using the re-measured skid trail, shall not differ by more than 10% from the initially measured value for that skid trail. Re-measurement for this purpose shall be done by different field personnel.
Purpose of data:	Calculation of emission reductions
Comments:	N/A

Data / Parameter:	FTD_t
Data unit:	Trees/ha
Description:	Felled tree density for application in Yucatan Peninsula: average of felled trees in annual harvest area from year t.
Equations	1, 2
Source of data:	This parameter is calculated following completion of each annual harvest based on the commercial timber inventory conducted prior to each annual harvest.
Description of measurement methods and procedures to be applied:	Complete enumeration via field census
Frequency of monitoring/recording:	Within two years after each annual harvest
QA/QC procedures to be applied:	Standard quality control / quality assurance procedures for forest inventory including field data collection and data management

	shall be applied. Standard operating procedures (SOPs) for field measurements shall be documented.
Purpose of data:	Calculation of emission reductions
Comments:	N/A

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APPENDIX 1: RIL-C REGIONAL FORESTRY BEST PRACTICES STAKEHOLDER WORKSHOP

Alianza MéxicoREDD+
Con la gente por sus bosques

Quantifying the Carbon Emissions of Forest Use on the Yucatan Peninsula



Forestry practices in forestry ejidos on the Yucatan Peninsula.

In order to get feedback from stakeholders in the Yucutan peninsula on the design of this module, and the specific parameters, The Nature Conservancy conducted a one-day workshop involving 44 participants composed of forest team members, forest technicians, government representatives, non-governmental entities, and research centers gathered into working groups to discuss the results and provide feedback. The workshop was held on March 4, 2016, in Felipe Carrillo Puerto, Quintana Roo.

Key messages

Wood harvesting is a major factor in forest degradation in rainforests but with the implementation of Best Forestry Practices (BFP), such as Low Impact Practices on CO_2 emissions (RIL-C), ejidos can reduce emissions and conserve biodiversity.

In this study, the highest carbon emissions correspond to the following forestry activities: lane damage, followed logging damage to branches and tips in clearings.

The study found that certified ejidos have the lowest carbon emission rate compared to other ejidos. Large ejidos that do not carry out drag lane planning have higher emissions than large ejidos that do perform this practice. Also, small ejidos that use agricultural tractors for extraction have lower emission rates than small ejidos where the wood is dragged with a Tree Farmer.

The four most important forestry practices the study recommends for promotion are: directional tree felling, use of 100 m winch cables, better drag lane planning, and timber extraction with agricultural tractors instead of Tree Farmers for the ecoregion.

Calculations show that best forestry practices can reduce carbon emissions by 1-ton per cubic meter harvested or more.

The baseline for carbon emissions from timber harvesting for the Yucatan Peninsula is estimated to be 1.18 tonnes carbon per cubic meter harvested.

Introduction

Forest management is a highly place-based activity, with many techniques, harvesting regimes, and practical challenges specific to particular regions (ITTO, 2005). A critical factor in the success of any forest management regime is therefore an understanding of local conditions and techniques. This workshop was intended as an expert consultation with long-time forest managers, government representatives, and other practitioners working on the ground. This opportunity functioned much as a group brainstorm to assess current practices and identify mechanisms for future improvement in harvest outcomes.

Globally, a total area of 350 million hectares of humid tropical forests are designated as production forests. Of these, about a quarter are managed by rural and indigenous communities (ITTO, 2005; White and Martin, 2002). These forests are mainly used for timber extraction, and with the increasing demand for this resource and increased access to forests, logging is likely to expand (Putz et al, 2008). In Mexico, forests cover more than 55.3 million hectares, with 22 million hectares corresponding to production forests (Rainforest Alliance, 2016; Ellis et al., 2015). In general, timber harvesting is a major factor in forest degradation in rainforests. Other factors include the harvesting of firewood, grazing, and the use of non-wood forest products (Griscom et al., 2009).

DEGRADATION VS DEFORFESTATION?
Forest degradation is the reduction of tree cover and/or forest carbon reserves through human activities without resulting in a change to a permanent non-forest land use (deforestation) (VCS Program *Definitions*). Degradation leaves >10% forest cover, does not include land use change, and is short-term. With good forest management, carbon reserves are maintained and can be carbon sinks.
Deforestation is the transformation of the forest into another land use or long-term reduction of the canopy cover below the minimum 10% threshold (FAO 2015). Deforestation includes forest changes that negatively affect the structure or function of the forest stand or site, reducing its ability to provide environmental products or services.
In this study, we focus on measuring the degradation caused by forest management activities.

While most of the discussions on REDD (Reduction of Emissions from Deforestation and Forest Degradation) focus on tropical deforestation, the potential to reduce emissions or store carbon through the reduction of forest degradation, has not been sufficiently promoted (Gullison et al., 2007; Da Fonseca et al., 2007). It is estimated that CO_2 emissions from forest degradation contribute a minimum of 20% of the total emissions generated in rainforest regions (Griscom et al., 2009). In addition, substantial reductions in global CO_2 emissions can be achieved by improving forest management in the tropics (Putz et al., 2008). It is even estimated that adopting Reduced Impact Logging (RIL) practices could reduce CO_2 emissions by 30-50% in at least 20% of the remaining tropical forests (Griscom et al., 2014).

RIL can be defined as intensive planning and carefully controlled wood extraction carried out by trained workers trying to minimize the harmful impacts of logging (Putz et al., 2008a). RIL reduces damage to the ecosystem through using forest operations planning that limits its alteration by heavy equipment and/or machinery and thus minimizes the effect to the remaining trees (Holmes et al., 2002). In some areas, where the RIL method is applied, environmental zoning restrictions are also used that prohibit logging in environmentally sensitive areas, which would otherwise be considered in conventional logging (CL) (ibid) operations. Researchers warn that RIL should never be a uniform or consistent set of harvesting practices (Griscom et al., 2014), given the wide diversity of tropical tree species, ecological differences and harvesting methods, in addition to the various objectives of different forest managers (Putz et al., 2008b). In particular, they recommend that RIL practices be adapted according to the conditions of each site in order to maintain diversity and forest connectivity.

Specific strategies that can be used to reduce forest degradation include: RIL, forest certification, integrated fire management, and sustainable wood management that incorporates agroforestry systems and alternative technologies like wood-saving stoves (Griscom et al., 2009). Forest certification (i.e., The Forest Stewardship Council, Rainforest Alliance) incorporates RIL and has the potential to reduce emissions through shrinking the harvest area, reducing volumes to sustainable levels, biomass retention, and reduction of the likelihood of forest conversion (ibid).

This study "Quantifying the carbon emissions of low-impact forestry on the Yucatan Peninsula" focuses on RIL-C (Reduced Impact Logging-Carbon), which is low-impact forest harvesting focused on CO^2 emissions. This strategy uses low-impact practices that minimize damage to the adjoining woodland and can, in effect, reduce carbon emissions while conserving biodiversity. RIL-C covers a variety of improved forest management practices (IFMs), such as directional felling, staging area and drag lane planning, alternative extraction methods (e.g., manual extraction or a smaller tractor) and other best practices that are being implemented in the region with potential to reduce carbon emissions (Ellis et al., 2014; VCS, 2015).

Within the Copenhagen Agreement of the UNFCCC (United Nations Framework Convention on Climate Change), including better forest management as a way to improve carbon sinks is considered and it suggests that forest restoration will play a role in mitigating global climate change. In Mexico, the government has committed to meet REDD+ targets through the General Law on Climate Change which establishes the framework for mitigation actions in the forestry sector. By 2020, Mexico must have zero net emissions associated with land use change and will also be increasing the quality of carbon reserves so that biodiversity and ecosystem integrity are preserved through actions such as sustainable forest management, conservation, and increasing carbon reserves (CONAFOR, 2013). By 2020, the national rate of forest degradation will have been significantly reduced from the reference level, while the sustainably managed forest area and carbon reserves will increase (CONAFOR, 2014). The development of the forest reference level in the country requires a combination of recent historical data on emissions associated with deforestation and/or forest degradation, and those of other relevant land uses, as well as the estimation of future emissions and sinks that would exist in the country if there were no additional incentives for REDD+.

Data collection is one of the most necessary first steps in order to contribute to the actions of REDD+ in Mexico. Therefore, the importance of the information obtained in this study "Quantifying the carbon

emissions of low-impact forest harvesting on the Yucatan Peninsula" serves to contribute to the measurement, reporting, and verification initiative (MRV) that is crucial for REDD+ to measure and monitor the performance of emissions reduction as a result of IFM on the Yucatan Peninsula. The main objectives of the study are: 1) to estimate carbon emissions by forest management and carbon additionality (or avoided emissions) resulting from best practices for forestry (BPF) or RIL-C in the Yucatan Peninsula; and 2) contribute the data and information needed to determine impact parameters and measure and verify carbon emission reductions by RIL-C practices. In addition, the study could provide information to the Forest Management Investment Programs (DPI) and the National Forestry Commission's (CONAFOR) Emissions Reduction Initiative (IRE) on the Yucatan Peninsula by identifying and proposing practices to reduce the emissions from degradation or deforestation.

WHAT IS RIL-C ?

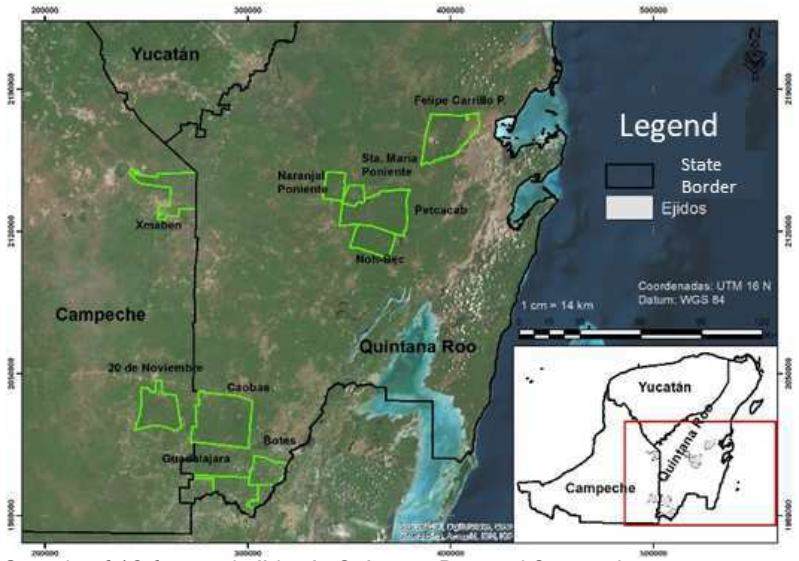
RIL-C (Reduced Impact Logging-Carbon) is a set of low-impact practices that minimize damage to surrounding forests and can, in effect, reduce carbon emissions and conserve biodiversity. On the Yucatan Peninsula, practices designated as RIL-C include directional felling, lane and staging area planning, alternative methods of timber extraction, cutting of brush before logging, etc.

Methods

The study is based on data collected from the previous consultancy of the TNC-MREDD+ Alliance called "A field survey of timber producing communities and assessing opportunities for improved forest timber management activities to reduce or stop greenhouse emissions within managed forests within Mexico," which identified a number of possible best forest management practices in forest stands in the states of Campeche and Quintana Roo (Ellis et al., 2014). The selection of ejidos in this study was based on a stratified sample of the varieties of forests in production within the ecoregion, including the 33 forest ejidos with active harvesting in 2013, according to official data from the Secretariat of Environment and Natural Resources (SEMARNAT). The ejidos were stratified according to their annual logging area (ACA) and forest management level (with BPF and forest certification, with BPF, and with forest management in development). Small ejidos contain ACAs of <500 hectares, while large ejidos have ACAs >500 hectares. Data to measure biomass on the ground and emissions from impacts and damage from forestry activities were collected in 2014 of the ACAs of 10 ejidos within the following categories:

- 2 Large Ejidos with RIL and FSC certification
- 2 Large Ejidos with RIL
- 2 Large Ejidos currently developing forest management
- 2 Small Ejidos with RIL
- 2 Small Ejidos currently developing forest management

In 2014, there were no small ejidos with forest certification to be included in the sample. In each large ejido, the impacts of harvesting on 200 ha within the ACAs were measured and 100 ha for small ejidos.



Sample of 10 forested ejidos in Quintana Roo and Campeche.

The ejidatarios participated in the field data collection with the prior permission of the Ejidal authorities. The data collected were:

1. GPS points of all staging areas, paths, lanes, and tree stumps found in the sampling area;
2. Staging areas: the dimensions and surface of all timber collection areas of the sample were measured;
3. Harvest clearings: diameter of stumps, the distance from the stump to the tip (trunk of the tree used), diameters of the tip and dap of all trees damaged by the felling (folded, broken, uncovered, slashed, scraped) with dap greater than 5 cm, including species information and whether it was commercial or not. Randomly selected clearings covering 5 to 10% of the total tree harvest area in the ACA;
4. Lanes: in 15 plots, 10 meter wide lanes were measured for damaged trees with dap greater than 5 cm within the plot with 100 m of distance between plots;
5. Roads: the width of the draw or extraction path was measured 20 times every 200 m;
6. Biomass (non-intervention area): Biomass was measured at 15 sites in unharvested areas with a basal area prism (2x2). Sites were randomly selected at the end of a drag lane;
7. Four allometric equations were used for the biomass calculation to estimate carbon, considering both roots and wood density.



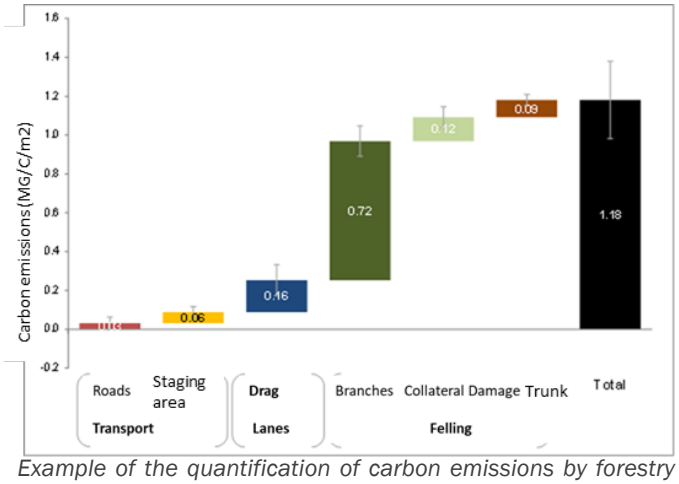
Measuring the staging area in the ACA of the ejido Felipe Carrillo Puerto, Quintana Roo, 2015.



Measuring collateral damage in the ejido Naranjal Poniente, Quintana Roo, 2015.

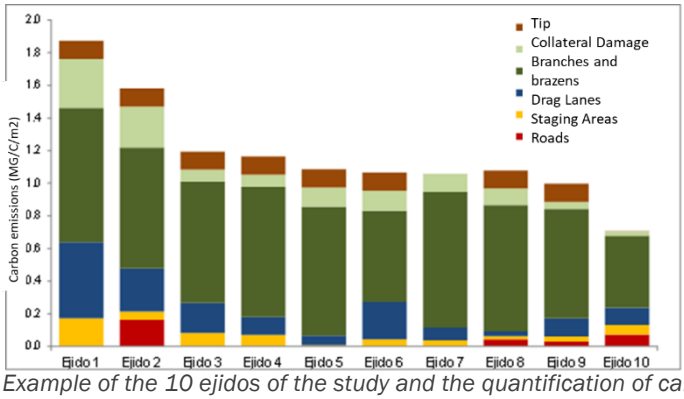
Results

After reviewing the carbon emissions of three categories of activities: transportation (including roads and staging areas), drag lanes, and felling area (includes trunk, branches and brazens, and collateral damage), we find that the highest emissions in forest management of the Yucatan Peninsula ecoregion correspond to: 1) branches and brazens, followed by 2) drag lane damage and 3) collateral damage.



Example of the quantification of carbon emissions by forestry activity in a large ejido with RIL management (+FSC certification).

Through comparing the quantity of carbon emissions by forest activity for the 10 ejidos of the study, we found that certified ejidos have the lowest carbon emission rate compared to other ejidos. Further, large ejidos that do not plan trawl lanes have higher emissions than large ejidos that do perform this practice. Also, small ejidos that use an agricultural tractor for extraction have lower emission rates than ejidos where the wood is dragged with a Tree Farmer. In general, few emissions were created by the creation of roads and staging areas, and in the felling of trunks. It is important to note that most ejidal forest management operations used and rehabilitated roads that were opened from the MIQRO (1950s) timber concession period. We found that it is rare for ejidos to open new roads and staging areas in their forest management area, which reduces the impacts of harvesting. Within the study, only three ejidos had opened new paths to harvest wood.



Example of the 10 ejidos of the study and the quantification of carbon emissions by forest activity.

In the maps generated of the ACAs of the ejidos involved in the study, using the reference points of stumps, there were several that were found outside of the harvest areas, which could imply that there is poor planning of delimitation of ACAs in the forested ejidos of the region or that there are errors in the GPS points of the borders with other ejidos.

By comparing the social factors or institutional agreements of the ejidos in the study, we note that factors such as the division of ejidatarios into working groups and/or the use of machinery by the buyers and brigades of loggers, who are not from the community, could contribute to the increase of carbon emissions in the forest harvesting activities. We believe that it would be necessary to further investigate social behavior in more detail in future studies.

Conclusions

The results of this study conclude that good forestry practices (RIL-C) can reduce emissions by up to 1 ton per cubic meter used or more on the Yucatan Peninsula. The highest emissions are from lane damage, followed by branches and tips and logging damage in felling. The reduction of lane damage is the most feasible and critical through good planning of the location of staging areas and drag lanes, in addition to the decrease of the width of lanes in meters per volume extracted, and the use of the most suitable technology or extraction method for the given conditions (i.e., Tractor vs. Tree Farmer, and winches cables that are more than 100 m). It is important to maintain communication with forest ejidos about how they can improve their lane planning. There is also a need to improve the training of ejidos' technicians regarding directional felling. In addition, it is important to train forestry machinery operators who work for timber buyers in the region. Focusing resources on improving these activities, including forest certification, can help reduce carbon emissions from forest harvesting on the peninsula.



Recommendations

On March 4, 2016, the results of the study "Quantifying the Carbon Emissions of Forest Use on the Yucatan Peninsula" were presented in the "RIL-C Workshop on the Implementation of Best Forestry Practices" in Felipe Carrillo Puerto. After reviewing the results and recommendations of the study, the 44 participants composed of forest team members, forest technicians, government representatives, non-governmental entities, and research centers gathered into working groups to discuss the results and provide feedback. Multisectoral participants discussed feasibility, barriers, and the benefits of implementing the proposed best forestry practices in forestry ejidos on the Yucatan Peninsula. They managed to reach a consensus and recommend the promotion of the following 11 practices that are listed in order of importance.

RECOMMENDATIONS OF RIL PRACTICES FOR THE YUCATAN PENINSULA	
1.	Better lane and road planning*
2.	Better use of branches and sticks
3.	Use of longer winches/cables*
4.	Establishment and planning of staging areas
5.	Directional takedown*
6.	Use of agricultural tractors*
7.	Increasing the efficiency of utilization
8.	Subdivision and delimitation of harvest areas

9.	Pre-cutting of the understory
10.	Good operation of Tree Farmers
11.	Shorter stumps
*The study's recommended practices to reduce carbon emissions (RIL-C)	

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For the complete workshop report please see this document.