Project Manual for Field Logging Emission Measurements

Contents

1. Background

Papua New Guinea (PNG) is well known as the country where one of the largest rain forest areas and its richest biodiversity remained in the world. On the other hand, forestry is one of the most important industries contributing to PNG's economy and rural development. According to PNG's reports submitted to UNFCCC (Forest Reference Level (FRL) and National REDD+ Strategy (NRS)), PNG still keeps forest

covering 78% of the country but large percentage of forest area has been degraded by commercial logging and it is actually the largest GHG emission source in PNG.

Although there is no PNG's specific methodology to monitor logging-associated emissions specifically, the Verified Carbon Standard (VCS)'s methodology, namely *"VM0035: Methodology for Improved Forest Management through Reduced Impact Logging"*, is available and could serve to meet this demand. Reduced Impact Logging (RIL), defined as "the intensively planned and carefully controlled implementation of timber harvesting operations to minimize the environmental impact on forest stands and soils (ITTO, 2017)", requires monitoring and assessment of direct impact of logging operation in terms of biomass loss, comparing with conventional logging practices. Since RIL could also contribute to climate change mitigation through reducing avoidable biomass loss by improved and careful logging operations, VM0035 has been applied for East Kalimantan Jurisdictional Emission Reductions Program in Indonesia funded by the World Bank's Forest Carbon Partnership Facility (FCPF) Carbon Fund, along with its module, titled *"VMD0047 Performance Method for Reduced Impact Logging in East and North Kalimantan"*.

Building based on this internationally certified methodology, the JICA-PNGFA Project has crafted a method to assess logging emissions at the setup level, referring to the context of PNG. This draft method enables the calculation of total biomass loss at the setup level, by the evaluating three key emission activities: Skidding, Felling, and Hauling. Based on the method, this manual has been prepared jointly by project members of PNGFA and JICA experts, in order to ensure the smooth and accurate collection of necessary field data.

2. Overview of Field Carbon Monitoring

As illustrated in the figure 2-1, the main sources of emission caused by commercial logging are not only Felling, but also Skidding and Hauling related activities. The emission caused by logging, therefore, can be calculated based on the biomass loss cased by those activities.

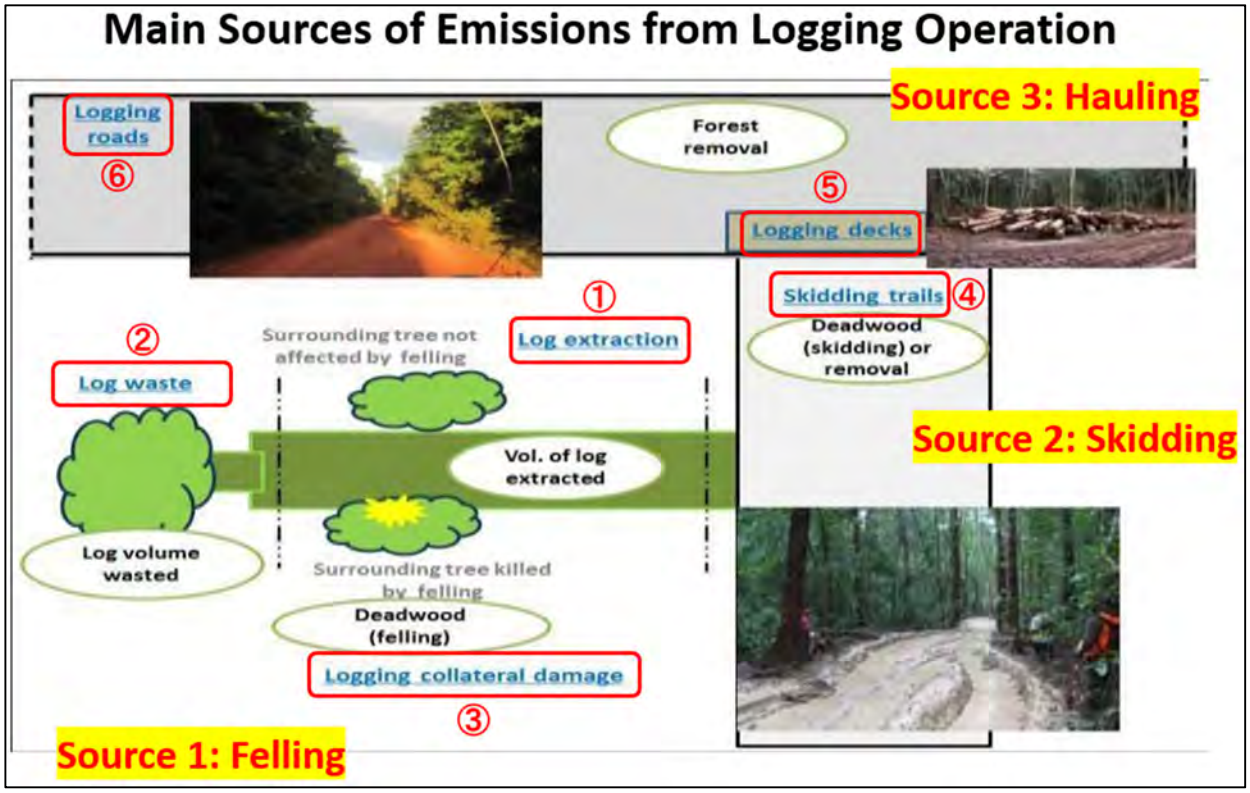


Figure 2-1: Sources of Emission

The following table gives you a clear picture of overview on survey items. In order to assess actual biomass losses, the listed survey items in the table 2-1 need be covered during the field carbon monitoring survey, by collecting required field measurement data (measurement parameters) listed in the table 2-2.

Emission Category	*Survey Items*
SKID	**Skid Track Area** at target setup
	(total length of both main and spur roads and average width)
	Skidding-caused Collateral Damage Impact at target setup
	(deadwood density per meter and total length)
	Natural Vegetation Carbon Stock Density
	(average carbon volume of natural vegetation per hectare)
FELL	**Felling-caused Damage Impact Density (Collateral Damage + Waste)** at target setup
	(deadwood and residue density per stump/tree and total number of tree felled)
	Log Extraction Impact of target setup
	(log extraction volume)
HAUL	**Hauling Road Area** at target setup
	(average width and length allocated for target setup)
	Total Log Landing Area at target setup
	(length and width of respective log landings)
	Natural Vegetation Carbon Stock Density
	(average carbon volume of natural vegetation per hectare)

Table 2-1: Survey Item

Sources of emissions					Measurement objects	Measurement values
Forest carbon stock damage from selective logging	Carbon stock damage in logging gaps due to tree felling	Timber-trees	Log volumes	Extracted log volumes	Lying/removed deadwood	Length (L), Diameters of top and bottom of logs (D1-D4)
				Non extracted log volumes: trimmed, abandoned, forgotten	Lying deadwood in logs	Length (L), Diameters of top and bottom of logs (D1-D4)
			Non log volumes	Stumps	Stump	Height (H), Diameters of stump (D1-D2)
				Tops, Head logs	Lying deadwood	Length (L), Diameters of head logs/tops (D1-D2)
		Other trees	Uprooted volumes		Lying deadwood (G)	Length (L), Diameters of uprooted trees (D1-D2)
			Snapped trees	Above the first branch	live tree (mortality<100%)	Not accounted here
				Below the first branch	Standing deadwood (S)	Height (H), DBH
	Area Damaged due to log extraction	Skid trails			Standing deadwood (S)	Height (H), DBH
					Lying deadwood (G)	Length (L), Diameters lying deadwood (D1-D2)
					Area removed	Skid trail width, length, area
		Log landings			Area removed	Landing width, length, area
		Haul logging roads			Area removed	Haul road width, length, area
		Others such as camps etc.			Area removed	Not accounted here

Table 2-2: Measurement Parameters

The scale of this field carbon monitoring survey is a setup level, which is the smallest operation unit of logging concession, as illustrated in figure 2-2. It is expected to scale up to the concession level estimation through increasing the number of sampled setups. The surveyers/participating FA officials are encouraged to follow the step-by-step guide provided below to collect acurate field data.

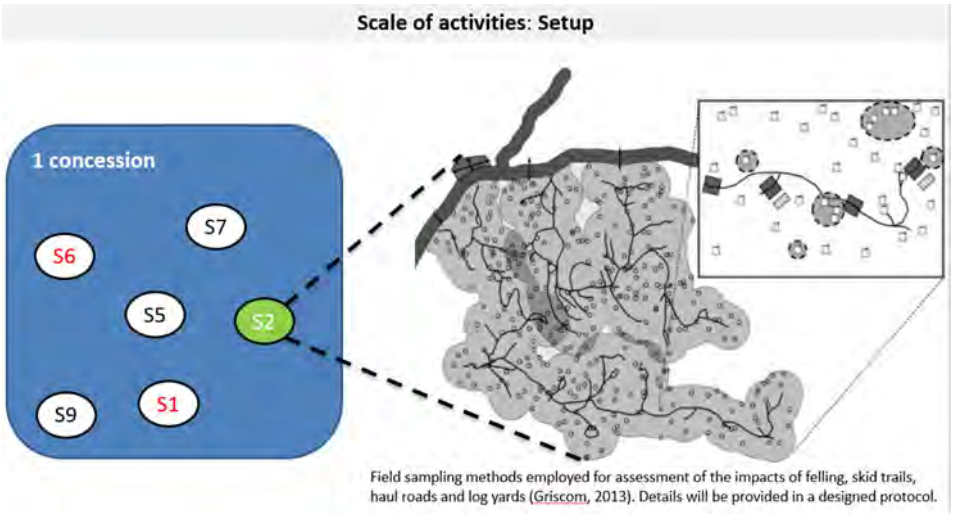


Figure 2-2: Scale of Field Carbon Monitoring

3. Preparation for the Survey

3.1 Generic information collection

To grasp an overall picture of targeted logging concession and creat a detailed survey plan, the following information should first be collected from Five Year Working Plan, Annual Logging Plan, record of logging activities submitted by companies to PNGFA. If certain data is not available at PNGFA, but deemed necessary, you should request logging company for sharing them in advance.

Data Source	Annual Logging Plan (located at PNGFA)	Logging Company	PNGFRIMS
Required Data	1) Official data of concession ➢ Concession number ➢ Permit holder ➢ Concession type ➢ Concession size 2) Forest Type 3) Dominant Species 4) List of Targeted Merchandable Species 5) Annual harvested timber volume of previous 1 or 2 years 6) Harvestable volume per hectare 7) Setup-wise area data (hectare) 8) Maps ➢ Concession-level (indicating coupe boundaries and hauling road network) ➢ Coupe where target setup falls into (indicating setup boundaries and log landing locations) ➢ Target setup (indicating skid track networks)	1) Log scaling data of target setup (log-wise measurement data) 2) Number of trees felled at target setup 3) Annual harvested timber volume of last 10 years	1) Satellite imagery data 2) Elevation 3) Topography (5-10m contour lines) 4) Soil type 5) Precipitation

Table 3-1: Required Information for Detailed Survey Planning

3.2 Required Human Resources for field survey

For effective field survey implementation, a total of six to ten survey members should be organized into two to three teams. Each team should consist of at least three members: two for measurement and one for recording. Each team should be led by a experienced team leader and other two are should follow instructions from the team leader.

3.3 Detailed planning of field survey

Based on maps and other information collected from ALP/provided by logging company, the detailed survey plan should be developed before departure, which indicates the locations of tareget hauling roads, skid track networks, log landing, survey lots, etc. Overview of the field survey could be like the below illustration (the details of each target will be explained in following sections). Please note that since field situations might be different from the information on the Annual Logging Plan or the ones obtained from the logging company, keeping flexibility in plan would be critically essential for comprehensive and throughout implementation of this field survey for field carbon monitoring.

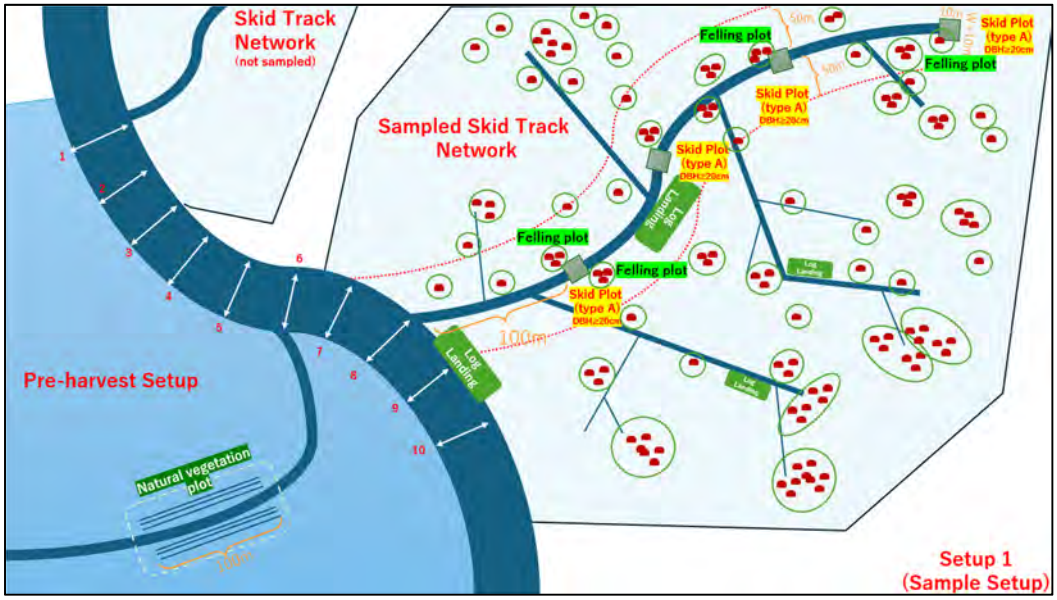


Figure 3-1: Overview of Survey Plots

3.4 Survey tools and materials

Proper preparation of tools is essentilal for conducting an effective field survey. The person(s) responsible for survery prepration must prepare the following tools and materials, listed in the table 3-1 before survey begins. These preparation must be verified by survey team that all necessary items are available. Coordination with relavant parties including provincial forest office and logging company should be conducted to secure all required materials before departing for the field.

No	Measurement tools and devices	Measurement type / activity
INFRASTRUCTURE		
1	GPS devices (one for respective survey teams)	Width and length of infrastructures
2	Flagging tape	
3	Measurement tape	
4	Clinometers / Laser range finder / Vertex	Slope Correction

5	Digital camera / video	Photo documentation if any
PLOTS		
6	GPS devices (one for respective survey teams)	Plot establishment
7	Flagging tape	
8	Measurement tape	
9	Clinometers / Laser range finder / Vertex	Slope Correction
10	Digital camera / video	Photo documentation if any
11	Densiometer, if available	Canopy closure
LIVING TREES		
12	Tree species determination keys (book, photo, etc.)	Species name
13	Diameter tape	Tree diameter
14	1.3 m pole if available	
15	Portable retractable ladder (3 to 5 m) if available	
16	Laser range finder / Vertex	Tree height
17	Clinometer (in case laser range finder does not work)	
18	Measurement tape (in case laser range finder does not work)	
STANDING DEADWOOD (SNAPPED BELOW FIRST BRANCH)		
19	Diameter tape	Standing deadwood diameter
20	Laser range finder / Vertex	Standing deadwood height
21	Clinometer (in case laser range finder does not work)	
22	Measurement tape (in case laser range finder does not work)	
STUMPS		
23	Diameter tape	Stump diameter and height
UPROOTED LYING DEADWOOD / LOG WASTES (RESIDUES)		
24	Diameter tape	Deadwood diameters
25	Measurement tape	Deadwood length
RECORDING		
26	Field record sheet	Recording measurement data
27	Clip board	
28	Waterproof document case	
29	Pencil	
30	Eraser	
31	Pen	

32	Crayon	Writing measurement data on cross section of trees/logs
33	Carrying bag / backpack	Carrying tools and devices

Table 3-2: Necessary tools and materials for field survey

4. Steps and Target Measurement Objects

4.1 Steps for data collection

The following is the overall guidance for steps for field carbon monitoiring, this manual, as well as field record sheets attached.

Emission Category	*Survey Items*	*Procedural Step No.*	*Manual Section No.*	*Field Record Sheet No.*
SKID	**Skid Track Area** at target setup (total length of both main and spur roads and average width)	2	5.4	FORM 2
	Skidding-caused Collateral Damage Impact at target setup (deadwood density per meter and total length)	3	5.5	FORM 3
	Natural Vegetation Carbon Stock Density (average carbon volume of natural vegetation per hectare)	6	5.11	FORM 6
FELL	**Felling-caused Damage Impact Density (Collateral Damage + Waste)** at target setup (deadwood and residue density per stump/tree and total number of tree felled)	4	5.7	FORM 4
	Log Extraction Impact of target setup (log extraction volume)	7	5.12	
HAUL	**Hauling Road Area** at target setup (average width and length allocated for target setup)	5	5.9	FORM 5
	Total Log Landing Area at target setup (length and width of respective log landings)	5	5.10	FORM 5
	Natural Vegetation Carbon Stock Density (average carbon volume of natural vegetation per hectare)	6	5.11	FORM 6

Table 4-1: Overall Guidance about Steps, Manual, and Field Record Sheets

For further details about steps, the following figure outlines respective steps for conducting a field survey at the setup area. Follwoing these steps will give you a clear view of the survey flow and movements at target setup.

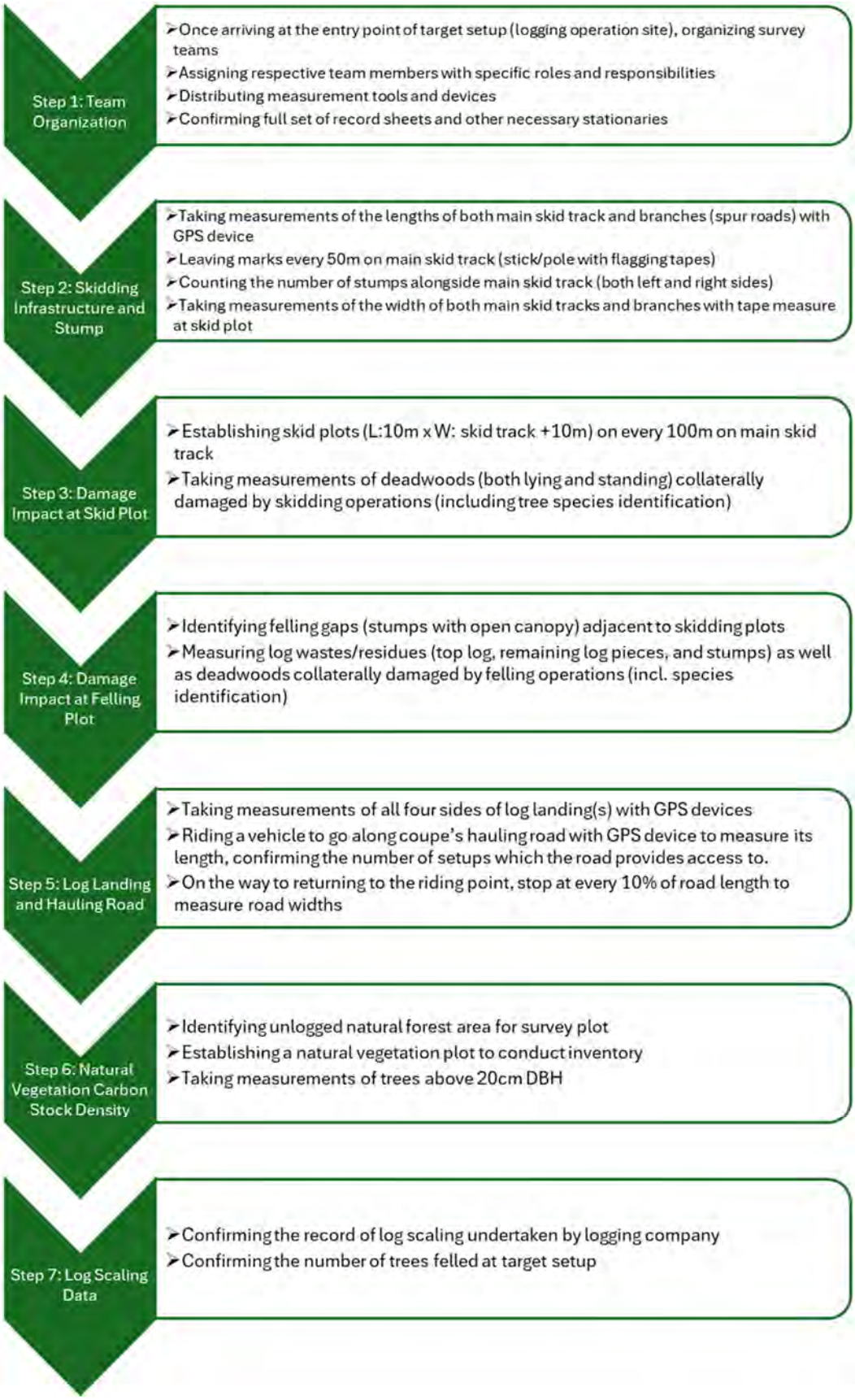


Figure 4-1: Steps for Field Survey at Setup Area

4.2 Target Objects to be measured

Target measurement objects are aleady listed in the table 2-2 but the following is a simplified summary. Please note that this methodology considers only tree form plants, dbh > 10 cm, h > 1.3 m, and therefore excludes any forms other than trees. Further details, please see the table below.

Measurement Target Objects	Non-target Objects
1) Tree	➢ Fern
➢ Standing trees (bigger than 10cm DBH and 1.3m height)	➢ Liana
➢ Standing deadwood (snapped below first branch)	➢ Palm
➢ Uprooted lying deadwood	➢ Pandanus
➢ Abondaned log	➢ Bamboo
➢ Stump	➢ Seedling
➢ Other residue (top log and log pieces)	➢ Coarse woody debris (<10cm)
2) Logging Infrastructure (hauling road, skid tracks, log landings)	➢ Litter, etc

Table 4-2: Target and Non-target Objects

5. Step-wise Procedure for Data Collection

5.1 Step 1: Team Organization

As mentioned above, each survey team should consist of at least three members, two for measurement and one for recording, and each team should be led by a experienced team leader who is responsible for recording all measurement data, and other two should follow instructions from the team leader to take mesurements in smooth manner. Since you hardly go back to the same site for re-measurement, the team leader/recorder needs to make sure that all the necessary measurement data are collected in acurate manner, not missing out any. For this purpose, team members should reconfirm the process of survey, target measurement objectives, measurement parameters, measurement methods, and recording, prior to starting your survey. Moreover, before heading to the target setup, the team should make sure to carry all of the necessary tools and equipment listed in table 3-2, while checking GPS devices are working properly. Once your team completes all necessary preparations for field survey, you should fill in the record sheet titled “FORM 1: General Information”.

Logging Carbon Monitoring Survey

FORM 1: General Information

Record Sheet Set No. _____

Date:	/ /
Day No.	1 2 3 4 5 6 7

(circule by day only)

1. Generic Information

Name of Field Recorder

Organization (Directorate, Division, Office, Section)

Position Title

Contact Number and Email

Mobile:	Email:

DATA ENTRY

Data Entry Date: _____

Name of Data Entry Officer:

Organization

Contact Number and Email

Mobile:	Email:

2. General Information

Location of Concession

Province:

LLG:

Site/Village:

Target Setup for Field Carbon Monitoring

Coupe No.	Setup No:
Size of Target Setup:	

When harvesting was conducted: / /

Number of trees felled

Number of logs produced

Volume of log produced m3

Completion of Log Scaling: YES / NO

Map: Concession ☐ Coupe ☐ Setup ☐

List of Taregted Merchantable Tree Species ☐

Annual Harvesting Volume Records (5-10years) ☐

Estimated timber density m3/ha

GPS Data

GPS Device Type

GPS Device Keeper

Starting Position (use 6 digits in decimal degrees)

GPS Y (landitude) S

GPS X (Longitude) E

Concessioner/Logging Company

Consession No.

Permit Holder's Name

Concession Type

Contact Details:

Contact Person 1

Mobile:	Email:

Contact Person 2

Mobile:	Email:

Survey Team Member

Team Leader

Team members

Field Assistants

Figure 5-1: Record Sheet for General Information

5.2 Introduction: Data collection for Skidding

For measuring impact of skidding operations, the following items need to be surveyed, taking necessary measurements at and around skid tracks.

- **Skid Track Area** at target setup
  (total length of both main track and branches/spur roads, and average width)
- **Skidding-caused Collateral Damage Impact** at target setup
  (deadwood density per meter and total length)

Please note that the skid track networks installed at the target setup can be confirmed in advance with the maps attached to Annual Logging Plan or the ones provided by the logging company. However, due to high probability that actual location of such planned infrastructure would be different from the original plan, you should double-check the skid tracks by field observations (especially confirming the location of all log landings, as skid track networks are tend to be developed from a log landing).

Box 1: How to measure carbon loss caused by skidding operation

Filed carbon monitoring method and procedures developed by JICA-PNGFA project defines that the following equation is applied for calculating total carbon loss caused by Skidding operatioins. In terms of natural vegetation carbon stock density, its details will be described in the Step 6.

Carbn loss by Skidding (SKID) = (Total length of skid track: main & branches) x (Average width of skid track) x (Natural Vegetation Carbon Stock Density per hectare)

+

(Average Collaterally Damaged Deadwoods, as Skidding Impact Density) x (Total length of skid track)

5.3 Step 2-1: Skid Track Length and Stumps

Firstly, you should randomly select two to three skid track networks as sample network. For actual measurement, you should start with measuring the length of skid track (both main and branches/spur roads) with GPS device(s) (in case not available, measurement tape can be utilized), starting from log landing lcoated at the head of skid track until its end, as illustrated in the figure 4-2.

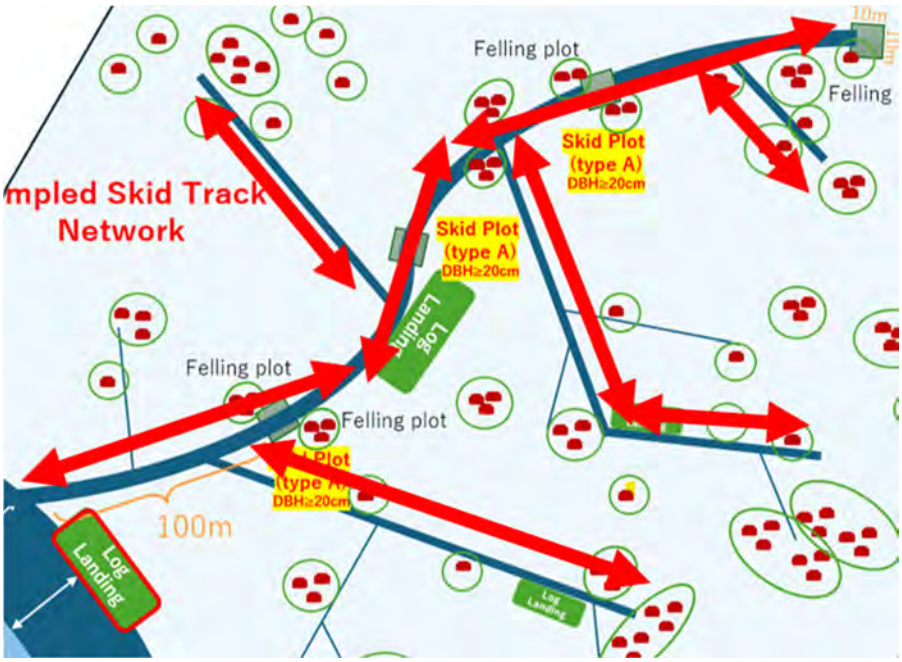


Figure 5-2: Skid Track Length Measurement

Meanwhile, at every 50m, a mark of pole/stick with flagging tape needs to be left on the main skid track, in order to easily confirm total length of skid track as well as locations for establishing Skid Plots, as described in the figure 4-3.

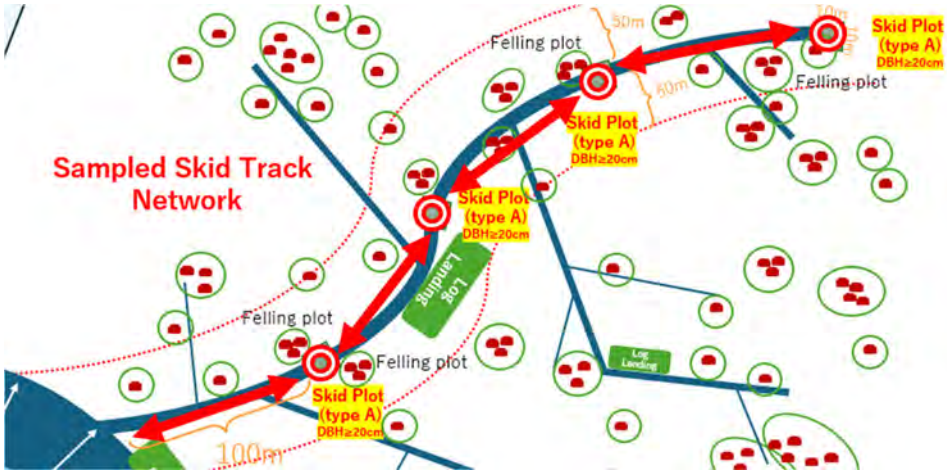


Figure 5-3: Marks for Skid Plot Establishment

Additionally, the survey team needs to count all stumps at both sides of the main track. Considering high probability of entering certain distance from the skid tracks for harvesting logs, it is important search all stumps within the range of 50m distance from skid track centerline, as indicated in the figure 4-4.

Figure 5-4: Stump Searching

5.4 Step 2-2: Skid Track Width Measurement

On the way to head back to the starting point, skid track width and skidding damage need be measured and assessed. At the marked points every 100m, skid plots need to be established. Its size should be 10m length and 5m distance from the edge of skid track at both sides (total width = skid track width + 10m), as illustrated in the figure 5-5. Before starting plot establishment, you should measure widths between the edge of skid tracks at/around top and bottom of skid plots at 10m distance (two widths per plot).

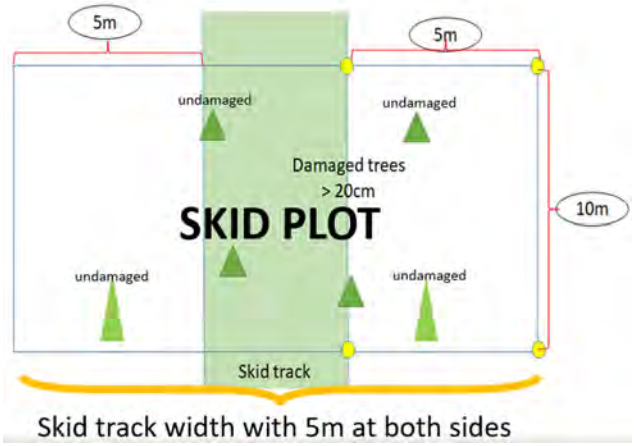


Figure 5-5: Design of Skid Plot

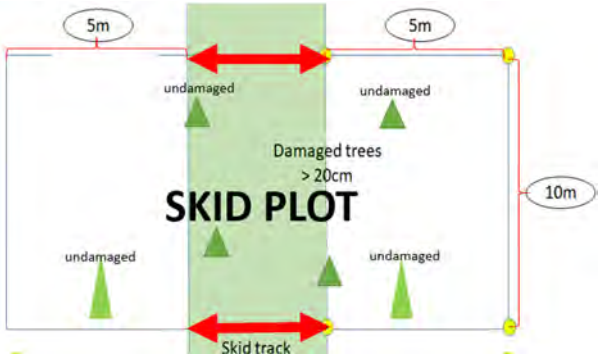


Figure 5-6: Skid Track Width Measurements

Once the team collects all the necessary data regarding skidding infrastructure (length and width) as well as numbers of tree stumps, the record sheet of FROM 2 “Skidding Infrastructure” should be completed.

Logging Carbon Monitoring Survey FORM 2: Skidding Infrastructure Page 1 /_____

		Track Length						Track Width		
Setup ID	Skid Track No.	Main Track (m)		Track Branch / Spur Road (m)		Stump No. alongside of main track		Skid Plot No.	Track Width (m)		Remarks
	ST___	1)		1)		Left		SP1	TW1		
				2)		Right			TW2		
				3)				SP2	TW1		
				4)					TW2		
				5)				SP3	TW1		
				6)					TW2		
				7)				SP4	TW1		
				8)					TW2		
				9)				SP5	TW1		
				10)					TW2		
	ST___	__)		__)		Left		SP___	TW1		
				__)		Right			TW2		
				__)				SP___	TW1		
				__)					TW2		

Figure 5-7: Record sheet for Skidding Infrastructure

5.5 Step 3: Damage impact at Skid Plot

Now you will assess actual damage impact of Skidding Opertaion. You should establish skid plots according to the above plot design (figure 5-5), and start measuring all lying and standing deadwoods. In terms of “Standing Deadwood”, it is necessary to identify the proper standing deadwoods, which are snapped below below first branch (the one snapped above its branch will not be measured as its mortality rate is less than 100%), as indicated in the fiture 5-8. In terms of measurements, the diameter of root collar as well as bole/trunk top diameter of standing deadwood needs to be measured together with length of remainig trunk.

For broken lying deadwood uprooted due to skidding operation, two diameters and length can be measured as illustrated in Figure 4-9. In case that uprooted trees are not snapped, DBH and tree height can be measured alternatively.

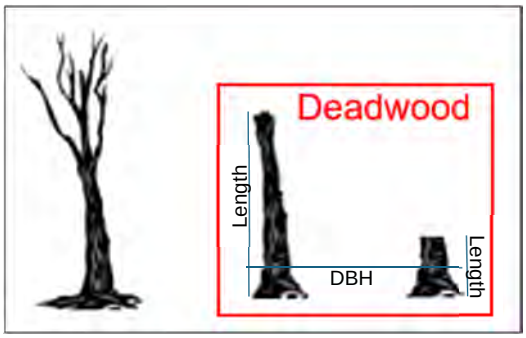


Figure 5-8: Standing Deadwood

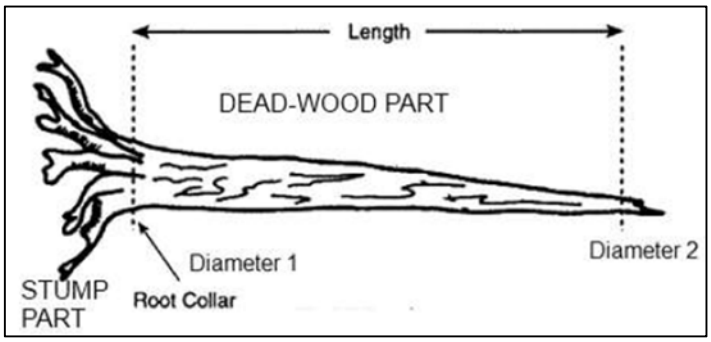


Figure 5-9: Uprooted Lying Deadwood

Here, skidding operations (bulldozering, log skidding) caused deadwoods identified inside Skid Plots shall be measured appropriately and recorded in the record sheet titled “FORM 3: Skidding Damage”.

Logging Carbon Monitoring Survey FORM 3: Skidding Damage Page 1 / _____

Setup ID	Skid Track No.	Skid Plot No.	Deadwood No.	Form L=Lying S=Standing	Tree Species	Height / Length (m)	Root Collar Diameter (cm)	Trunk Top Diameter (cm)	Remarks
	ST1	SP1	S-CD1						
	ST___	SP___	S-CD2						
	ST___	SP___	S-CD3						
	ST___	SP___	S-CD4						
	ST___	SP___	S-CD5						
	ST___	SP___	S-CD6						
	ST___	SP___	S-CD7						
	ST___	SP___	S-CD8						
	ST___	SP___	S-CD9						
	ST___	SP___	S-CD10						
	ST___	SP___	S-CD11						
	ST___	SP___	S-CD12						

Figure 5-10: Record Sheet for Deadwoods within Skid Plot

5.6 Introduction: Data collection for Felling

Next step is about Felling Impact. In order to calculate felling-caused carbon loss, two different types of data will be required: 1) felling-caused damage and 2) log extraction volume.

- **Felling-caused Damage Impact Density (Collateral Damage + Waste)** at target setup
  (deadwood and residue density per stump/tree and total number of tree felled)
- **Log Extraction Impact** of target setup
  (log extraction volume)

For total log volume extracted from the target setup, you should collect Log Scaling Data after completing field works (further will be spelled out at Step 7). Here, the focus of field measurements for felling-caused carbon loss is on the log wastes/residues and collaterally damaged deadwoods within felling gaps, which are the open canopy area created by harvesting (felling one or more trees).

Box 2: How to calculate carbon losses caused by felling operation

According to the Filed carbon monitoring operating method and procedures, carbon loss caused by felling operation can be calculated based on the following equation.

Carbon loss by Felling (FELL) = {(Average felling-caused carbon loss per stump: log wastes/residues & collateral damaged deadwoods)} x (Total number of felled trees)

+

(Extracted Logs’ carbon)

5.7 Step 4: Damage Impact at Felling Plot

Your team should take necessary measurements of Log Wastes/Residues and Collateral Damaged Deadwood by Felling at Felling Plot. The following are the details.

① Log Wastes/Residues (please see the figure below)

- Abondoned Log: diameers of both ends and its length
- Top Log: diameter and length of remaining trunk
- Log Piece(s): diameters of both ends and its length
- Stump: top diameter and height

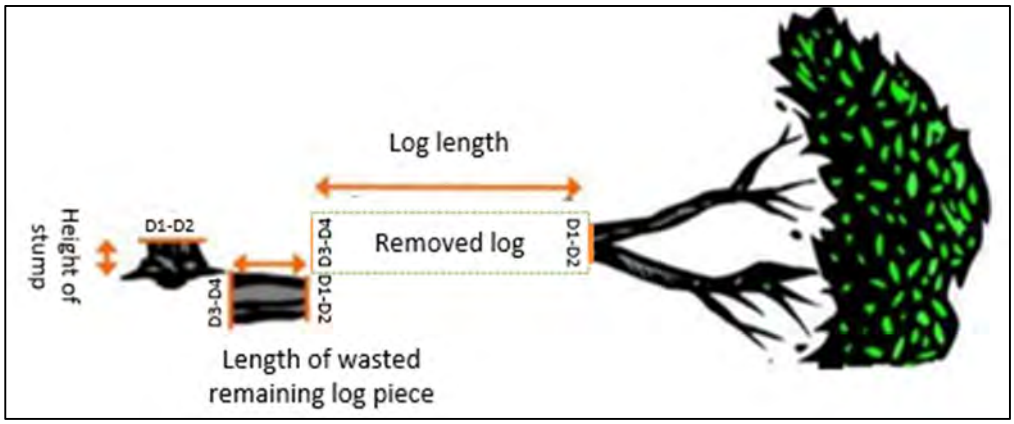


Figure 5-11: Log Wastes/Residues

② Collaterally damaged deadwoods (please refer to Figure 5-8 and 5-9 for further details)

- Uprooted lying deadwood: diameters of both ends and length (or DBH and height)
- Standing deadwood snapped below first branch: diameters (root collar and trunk top) and length

Since the felling gap might be with full of random debris, it is critical to identify a stump first, and then other associated residues, like top log and other log pieces, for taking measurements. You should make sure to group all identified residues with same tree ID (i.e., same F-TR1 for stump, log piece,and top log). After completing all measurements, you should complete filling in the record sheet for felling plot, which is “FROM 4: Felling Damage”.

Logging Carbon Monitoring Survey FORM 4: Felling Damage Page 1 / ______

Setup ID	Skid Track No.	Felling Plot No.	Tree ID	Object Type	Form L=Lying S=Standing	Tree Species	Height / Length (m)	D1 (cm) Root Collar Diameter	D2 (cm) Trunk Top Diameter	D3 (cm) Only in case that diameter cannot be measured with	D4 (cm)	Remarks
	ST1	FP1	F-TR1									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST	FP	F-TR									

Figure 5-12: Record Sheet for Log Wastes and Deadwoods by Felling

5.8 Introduction: Data collection for Hauling

Next step is about Hauling Infrastructure. There are two different types of hauling infrastructure you can find in the target setup, which are 1) Hauling Road, and 2) Log Landings. Since hauling infrastructure measurement will be undertaken after completing skidding and felling related measurement inside the forests, log landings will be measured first, and then hauling road.

- **Hauling Road Area** at target setup
  (average width and length allocated for target setup)
- **Total Log Landing Area** at target setup
  (length and width of respective log landings)

Box 3: How to calculate carbon loss caused by Hauling

Similar to above two emission activities, the carbon loss caused by Hauling can be calculated by the following equation. The natural vegetation carbon stock density will be calculated at the Step 6.

Carbon loss by Hauling (HAUL) = (Average hauling road width) x (Length of hauling roads allocated for target setup) x (Natural Vegetation Carbon Stock Density)

+

(Total size of log landings) x (Natural Vegetation Carbon Stock Density)

5.9 Step 5-1: Log Landings

The target of next measurement is log landings while returning from skid track to the starting point. A main Log landing is located at the head of skid tack network, but there might be another sub log landing,

established at the middle of main skid tracks. You should measure the size of all log landings with GPS device(s), or alternatively by measurement tape in case GPS is not available.

Then, you also should search for other log landings in other skid tracks so as to figure out its total number within the same sampled setup. At least, you should take measurements of 3 log landings, if there are more than two. Then, you should fill in the upper part of the record sheet titled “FORM 5: Hauling Infrastructure”.

Logging Carbon Monitoring Survey Page ____ / _____

FORM 5: Hauling Infrastructure

In case of measuring with tape measure

Setup ID	Log Landing No	Length (m)	Width (m)	GPS Measurement Result (ha)	Remarks
	LL 1				LL location: ST1
	LL 2				
	LL 3				
	LL 4				
	LL 5				
	LL 6				
	LL 7				
	LL 8				

Figure 5-13: Upper part of Record Sheet for Log Landings

5.10 Step 5-2: Hauling Road

After measurement of log landings, you should ride a car and go along the hauling roads by car with GPS devices, in order to measure the length of the hauling roads. The starting and ending point of this road length measurement can be identified based on map attached to Annual Logging Plan, or provided by logging company, and then at the field through consulting with logging company staff. For instance, if one haling road provides access to three setups, the length of hauling road should be between the ends of farest setups and then will be divided by three setups. Please refer to the figure below for your reference.

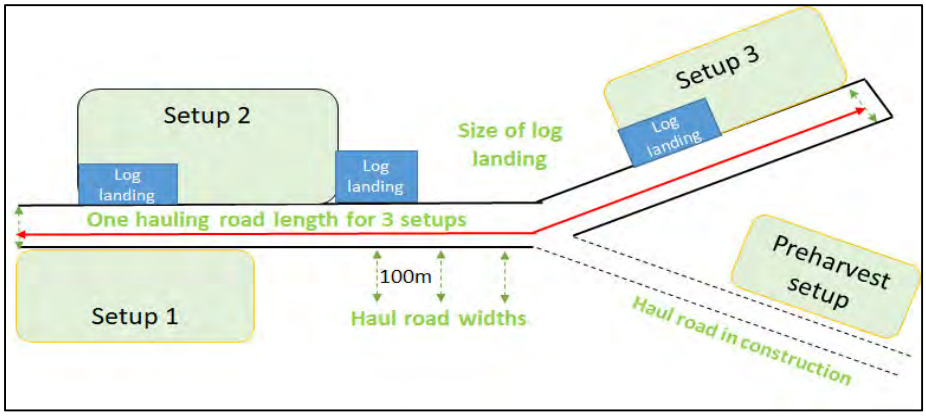


Figure 5-14: Hauling Road Length

Once you complete measuring the length of hauling road at ending point, you should stop at every 10% of total road length on the way to return to the starting point, in order to measure hauling road widths for ten times. You should also count the number of setups which the same road provides access to. Then, the lower part of “FROM 5: Hauling Infrastructure” should be filled.

Setup ID	Hauling Road ID	Road Length (m)	Rord Width No.	Road Width (m)	No. of steups the road provides access to
	HR 1		Width 1		
			Width 2		
			Width 3		
			Width 4		
			Width 5		
			Width 6		
			Width 7		
			Width 8		
			Width 9		
			Width 10		

Figure 4-15: Record Sheet for Hauling Road Width and Length

5.11 Step 6: Natural Vegetation Carbon Stock Density

For carbon loss caused by Skidding and Hauling, natural vegetation carbon stock density per area (ha) is essentially needed, as construction of such infrastructure could cause the clearance of unlogged natural forests or naturally regenerated forests from previous selective logging. In case of concession on naturally regerated forests, potential restored carbon stocks could be assessed based on actual years of forest

regrowth after selective logging operation conducted in the past, as investigaed and proved by Fox et al (2011)[1]. In case that previous logging operation was occurred more than 20 years ago, full biomass is assumed to be recovered in disturbed forests, while estimated biomass recovered can be calculated based on Fox's equation in case of less than 20 years (please refer to the literature for further details).

For conducting inventory of unlogged forest or naturally regerated forest, you should consult with logging company side to identify appropriate site, and then establish a survey plot (Natural Vegetation Plot) of 100m strip lines, as described in the below figure.

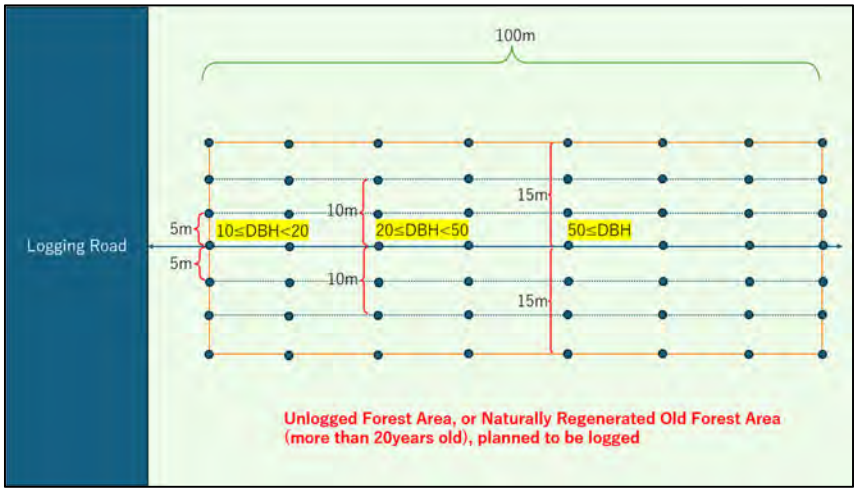


Figure 5-16: Design of Natural Vegeration Plot

At the identified site, a sample plot of 0.3ha (15m x both sides x 100m strip line) should be established according to the above plot design, and tree measurements should be conducted based on different thresholds; big size trees of 50cm≤DBH can be measured within the 15m distance from the centerline, while midium size trees of 20≤DBH<50 within 10m distance and small size trees of 10≤DBH<20 in the 5m distance respectively. DBH of all trees found inside the plot needs to be measured according to the above thresholds, while measurement of height can be carried out for every 4 trees as well as all trees above 40cm DBH.

Since establishing a plot in natural forests is not easy due to unclear views, you should start by setting 100m strip line, marking every 10-15m and then enter to both sides of the centerline, leaving other marks every 5m until reaching 15m (please see the figure 5-17). Meanwhile, you should take measurements of trees every 5m. All the collected data shall be recorded properly in the record sheet of "FROM 6: Natural Begetation".

[1] Fox J.C., Keenan R.J., Brack C.L. and Saulei S. (eds) 2011. Native forest management in Papua New Guinea: advances in assessment, modelling and decision-making. ACIAR Proceedings No. 135. Australian Centre for International Agricultural Research: Canberra. 201 pp.

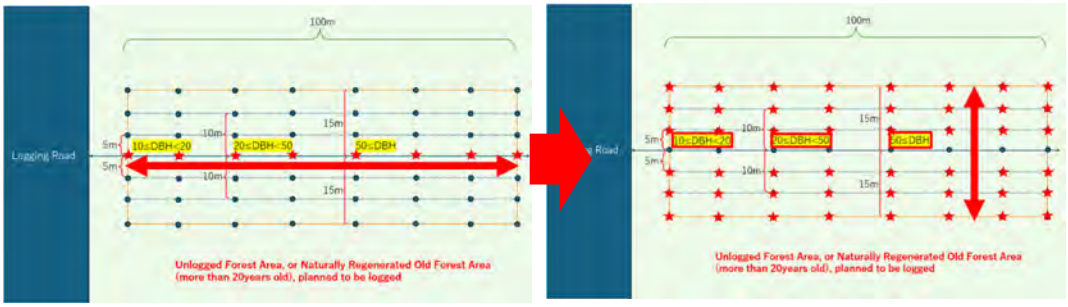


Figure 5-17: Process to establish a Natural Vegetation Plot

Logging Carbon Monitoring Survey Page 1 / ____

FORM 6: Natural Vegetation

Location *(Left/Right side of Strip line)*	***Tree ID***	***Tree Species***	***Height (m)***	***DBH (cm)***	***Remarks*** *(in case laser range finder does not work, please write angle and distance here)*
	NV-TR1				
	NV-TR2				
	NV-TR3				
	NV-TR4				
	NV-TR5				
	NV-TR6				
	NV-TR7				
	NV-TR8				
	NV-TR9				
	NV-TR10				
	NV-TR11				
	NV-TR12				
	NV-TR13				
	NV-TR14				
	NV-TR15				
	NV-TR16				

Figure 4-18: Record Sheet for Natural Vegetation

5.12 Step 7: Log Scaling Data

As part of Felling-caused carbon loss calculation, total volume of logs extracted from the target setup is vitally needed. You should request logging company to submit the Log Scaling Data, which is mandatory work defined by PNG regulations. This data should be, not just total extracted log volume, but log-wise measurement data sheet (diameter, length, and tree species), for accurate carbon calculation. In addition to the log scaling data, you should obtain the total number of trees felled at the setup. In case that the

logging company has not completed log scaling, you should officially request them to undertake mandatory log scaling.

<After Data Collection>

Once field data collection is completed, filled forms should be collected by the team leader for data entry on the format. Carbon calculations using the spreadsheet will be guided by another manual with step-by-setp guidance.

[END]

Attachment: Field Record Sheet Set

Attachment: Field Record Sheet Set

Logging Carbon Monitoring Survey

Record Sheet Set No. _____

FORM 1: General Information

Date:	/ /
Day No.	1 2 3 4 5 6 7

(circle by day only)

1. Generic Information

Name of Field Recorder

Organization (Directorate, Division, Office, Section)

Position Title

Contact Number and Email

Mobile:	Email:

DATA ENTRY

Data Entry Date: _____

Name of Data Entry Officer:

Organization

Contact Number and Email

Mobile:	Email:

2. General Information

Location of Concession

Province:

LLG:

Site/Village:

Target Setup for Field Carbon Monitoring

Coupe No.	Setup No:

Size of Target Setup:

When harvesting was conducted: / /

Number of trees felled

Number of logs produced

Volume of log produced m3

Completion of Log Scaling: YES / NO

Map: Concession ☐ Coupe ☐ Setup ☐

List of Targeted Merchantable Tree Species ☐

Annual Harvesting Volume Records (5-10years) ☐

Estimated timber density m3/ha

GPS Data

GPS Device Type

GPS Device Keeper

Starting Position (use 6 digits in decimal degrees)

GPS Y (longitude) S

GPS X (Longitude) E

Concessioner/Logging Company

Concession No.

Permit Holder's Name

Concession Type

Contact Details:

Contact Person 1

Mobile:	Email:

Contact Person 2

Mobile:	Email:

Survey Team Member

Team Leader

Team members

Field Assistants

Measurement tools and devices: Checklist

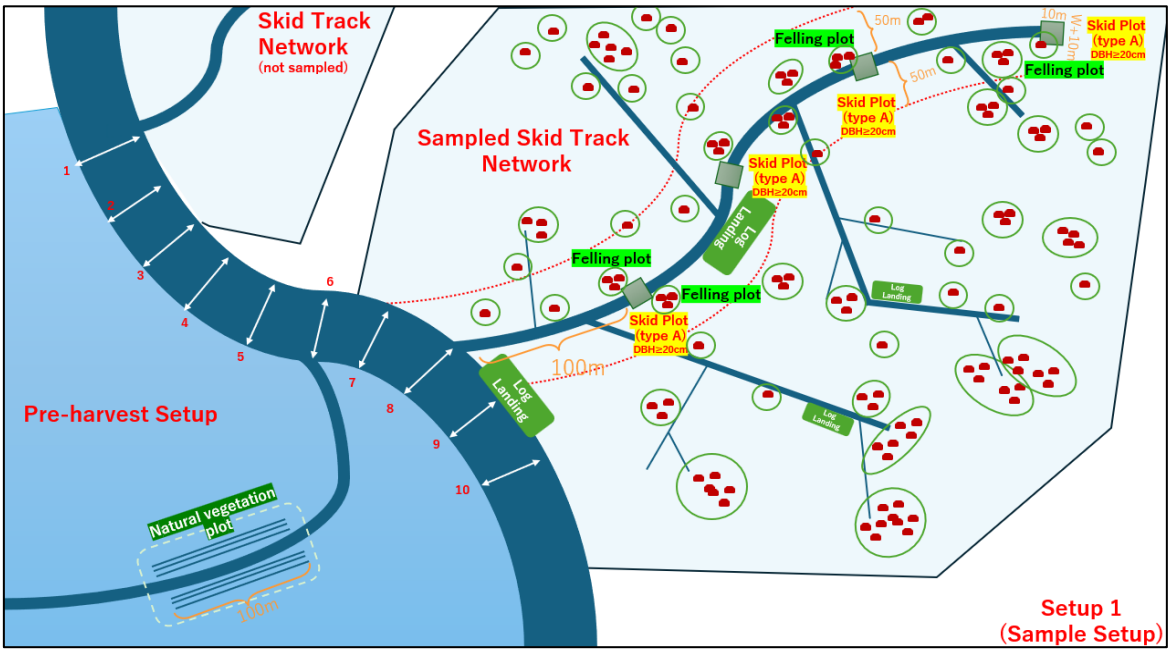
No	Measurement tools and devices	Measurement type / activity	Check Box
	INFRASTRUCTURE		
1	GPS devices (one for respective surve teams)	Width and length of instrastructures	☐
2	Flagging tape		☐
3	Measurement tape		☐
4	Clinometers / Laser range finder / Vertex	Slope Correction	☐
5	Digital camera / video	Photo documentation if any	☐
	PLOTS		
6	GPS devices (one for respective surve teams)	Plot establishment	☐
7	Flagging tape		☐
8	Measurement tape		☐
9	Clinometers / Laser range finder / Vertex	Slope Correction	☐
10	Digital camera / video	Photo documentation if any	☐
11	Densiometer	Canopy closure	☐
	LIVING TREES		
12	Tree species determination keys (book, photo, etc.)	Species name	☐
13	Diameter tape	Tree diameter	☐
14	1.3 m pole if available		☐
15	Portable retractable ladder (3 to 5 m) if available		☐
16	Laser range finder / Vertex	Tree height	☐
17	Clinometer (in case laser range finder does not work)		☐
18	Measurement tape (in case laser range finder does not work)		☐
	STANDING DEADWOOD (SNAPPED BELOW FIRST BRANCH)		
19	Diameter tape	Standing deadwood diameter	☐
20	Laser range finder / Vertex	Standing deadwood height	☐
21	Clinometer (in case laser range finder does not work)		☐
22	Measurement tape (in case laser range finder does not work)		☐
	STUMPS		
23	Diameter tape	Stump diameter and height	☐
	UPROOTED LYING DEADWOOD / LOG WASTES (RESIDUES)		
24	Diameter tape	Deadwood diameters	☐
25	Measurement tape	Deadwood length	☐
	RECORDING		
26	Field record sheet	Recording measurement data	☐
27	Clip board		☐
28	Waterproof document case		☐
29	Pencil		☐
30	Erazer		☐
31	Pen		☐
32	Crayon	Writing measurement data on cross section of trees/logs	☐
33	Carrying bag / backpack	Carring tools and devices	☐

MEMO:

Guidance for Survey

Emission Category	*Survey Items*
SKID	**Skid Track Area** at target setup
	(total length of both main and spur roads and average width)
	Skidding-caused Collateral Damage Impact at target setup
	(deadwood density per meter and total length)
	Natural Vegetation Carbon Stock Density
	(average carbon volume of natural vegetation per hectare)
FELL	**Felling-caused Damage Impact Density (Collateral Damage + Waste)** at target setup
	(deadwood and residue density per stump/tree and total number of tree felled)
	Log Extraction Impact of target setup
	(log extraction volume)
HAUL	**Hauling Road Area** at target setup
	(average width and length allocated for target setup)
	Total Log Landing Area at target setup
	(length and width of respective log landings)
	Natural Vegetation Carbon Stock Density
	(average carbon volume of natural vegetation per hectare)

Survey Items



Overview of Survey Plots

Guidance for Survey

Step 1: Team Organization

- Once arriving at the entry point of target setup (logging operation site), organizing survey teams
- Assigning respective team members with specific roles and responsibilities
- Distributing measurement tools and devices
- Confirming full set of record sheets and other necessary stationaries

Step 2: Skidding Infrastructure and Stump

- Taking measurements of the lengths of both main skid track and branches (spur roads) with GPS device
- Leaving marks every 50m on main skid track (stick/pole with flagging tapes)
- Counting the number of stumps alongside main skid track (both left and right sides)
- Taking measurements of the width of both main skid tracks and branches with tape measure at skid plot

Step 3: Damage Impact at Skid Plot

- Establishing skid plots (L:10m x W: skid track +10m) on every 100m on main skid track
- Taking measurements of deadwoods (both lying and standing) collaterally damaged by skidding operations (including tree species identification)

Step 4: Damage Impact at Felling Plot

- Identifying felling gaps (stumps with open canopy) adjacent to skidding plots
- Measuring log wastes/residues (top log, remaining log pieces, and stumps) as well as deadwoods collaterally damaged by felling operations (incl. species identification)

Step 5: Log Landing and Hauling Road

- Taking measurements of all four sides of log landing(s) with GPS devices
- Riding a vehicle to go along coupe's hauling road with GPS device to measure its length, confirming the number of setups which the road provides access to.
- On the way to returning to the riding point, stop at every 10% of road length to measure road widths

Step 6: Natural Vegetation Carbon Stock Density

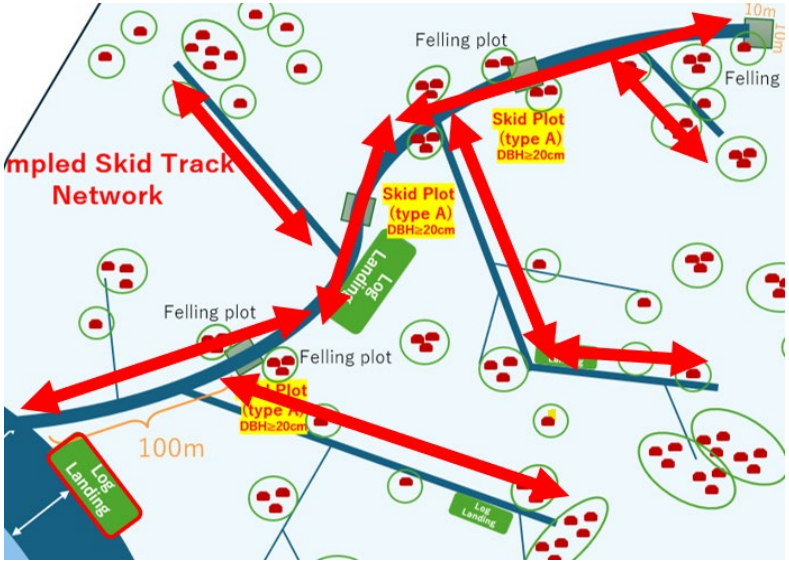
- Identifying unlogged natural forest area for survey plot
- Establishing a natural vegetation plot to conduct inventory
- Taking measurements of trees above 20cm DBH

Step 7: Log Scaling Data

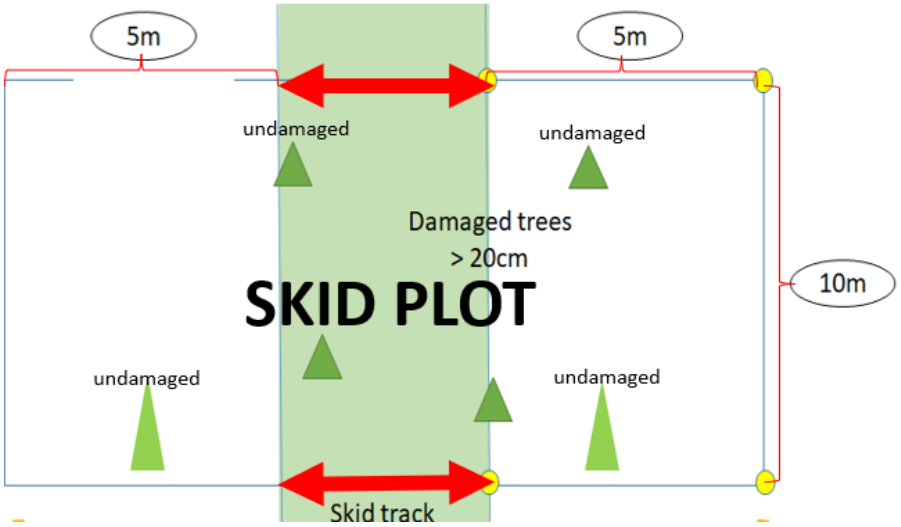
- Confirming the record of log scaling undertaken by logging company
- Confirming the number of trees felled at target setup

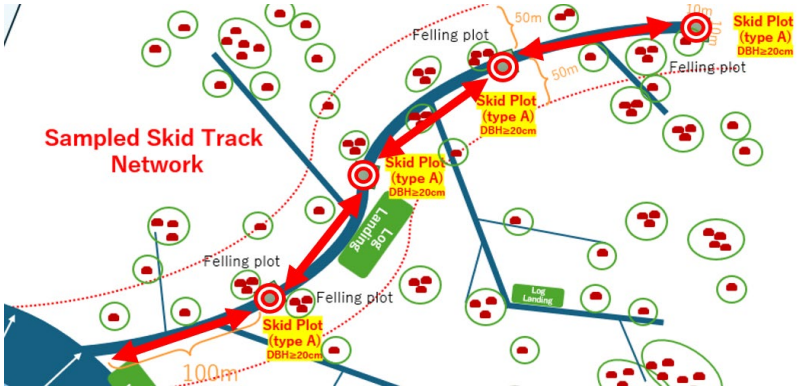
Steps for Field Survey

Measurement of Skidding Intrastructure and Stumps

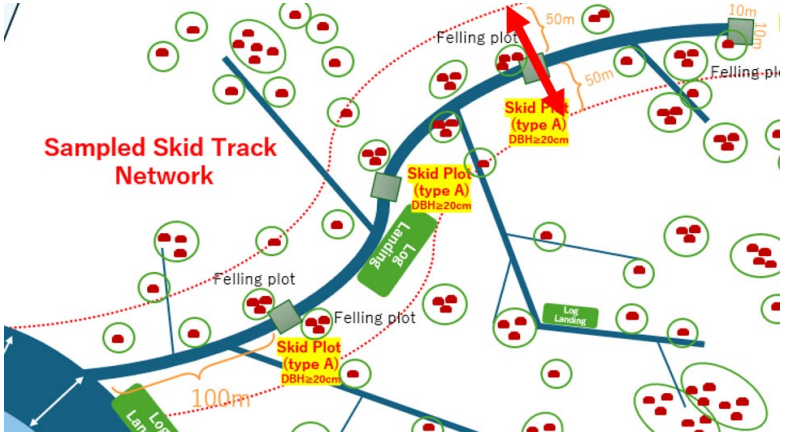


Skid Track Length Measurement





Marks for Skid Plot Establishment



Stump Searching

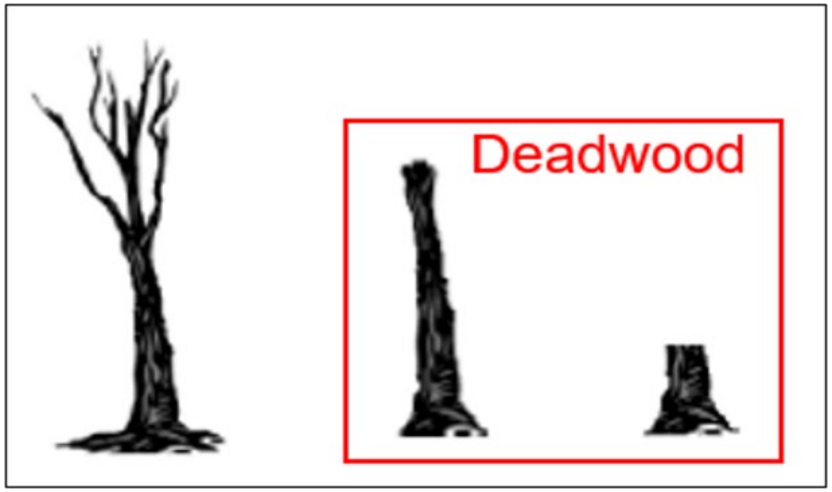
Design of Skid Plot &
Measurement of Skid Track Width (two times)

Logging Carbon Monitoring Survey

FORM 2: Skidding Infrastructure

		Track Length						Track Width			
Setup ID	***Skid Track No.***	***Main Track (m)***		***Track Branch / Spur Road (m)***		***Stump No. alongside of main track***		***Skid Plot No.***	***Track Width (m)***		***Remarks***
	ST___	1)		1)		**Left**		**SP1**	TW1		
				2)		**Right**			TW2		
				3)				**SP2**	TW1		
				4)					TW2		
				5)				**SP3**	TW1		
				6)					TW2		
				7)				**SP4**	TW1		
				8)					TW2		
				9)				**SP5**	TW1		
				10)					TW2		
	ST___	__)		__)		**Left**		**SP___**	TW1		
				__)		**Right**			TW2		
				__)				**SP___**	TW1		
				__)					TW2		
				__)				**SP___**	TW1		
				__)					TW2		
				__)				**SP___**	TW1		
				__)					TW2		
				__)				**SP___**	TW1		
				__)					TW2		

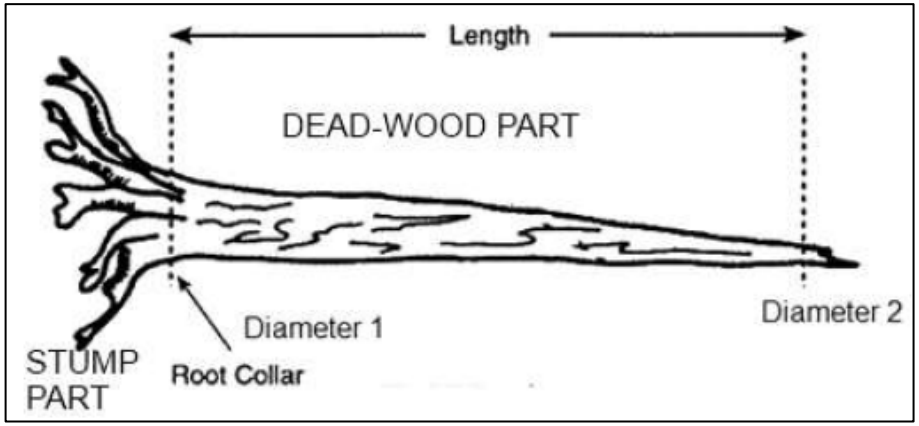
Measurement of Skidding-caused Deadwood at Skid Plot



Measurement Target: Standing Deadwood snapped below first branch

Measurement Parameters of Standing Deadwood:

1) Diameter of Root Collar (by diameter tape)
2) Diameter of bole/trunk top (by diameter tape if measurable, if not rough estimation)
3) Length from root collar to bole/trunk top (by laser range finder/Vertex)



Measurement Target: Uprooted Lying Deadwood

Measurement Parameters of Lying Deadwood:

1) Diameter of Root Collar (by diameter tape)
2) Diameter of bole/trunk top (by diameter tape)
3) Length from root collar to bole/trunk top (by tape measure)

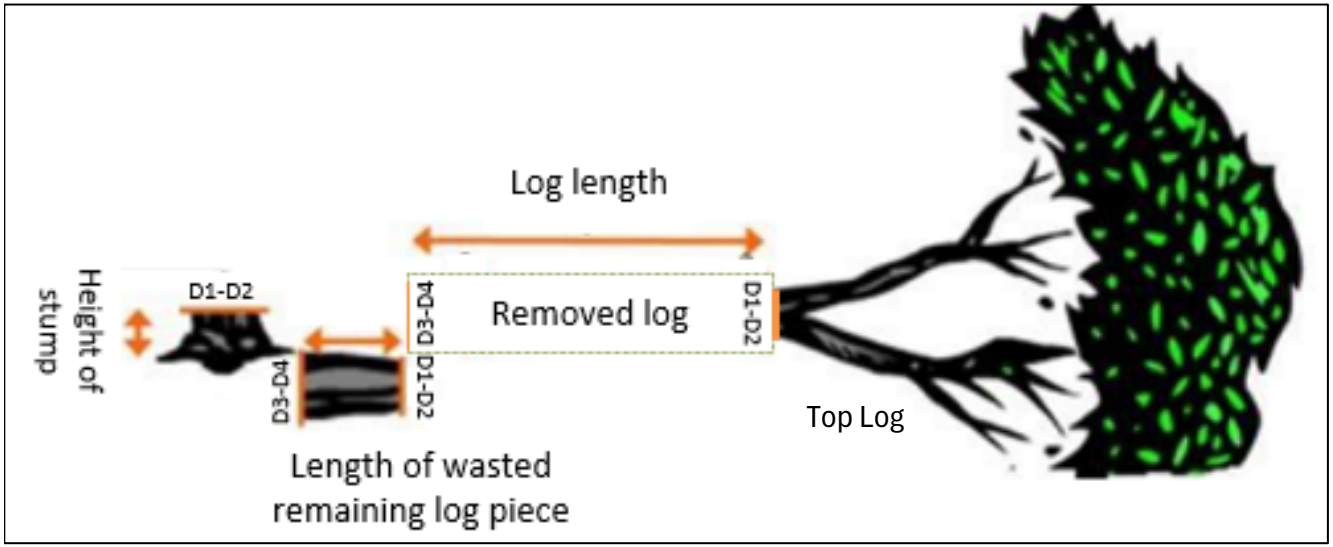
Logging Carbon Monitoring Survey

FORM 3: Skidding Damage

Setup ID	*Skid Track No.*	*Skid Plot No.*	*Deadwood No.*	*Form L=Lying S=Standing*	*Tree Species*	*Height / Length (m)*	*Root Collar Diameter (cm)*	*Trunk Top Diameter (cm)*	*Remarks*
	ST1	SP1	S-CD1						
	ST___	SP___	S-CD2						
	ST___	SP___	S-CD3						
	ST___	SP___	S-CD4						
	ST___	SP___	S-CD5						
	ST___	SP___	S-CD6						
	ST___	SP___	S-CD7						
	ST___	SP___	S-CD8						
	ST___	SP___	S-CD9						
	ST___	SP___	S-CD10						
	ST___	SP___	S-CD11						
	ST___	SP___	S-CD12						
	ST___	SP___	S-CD13						
	ST___	SP___	S-CD14						
	ST___	SP___	S-CD15						
	ST___	SP___	S-CD16						
	ST___	SP___	S-CD17						
	ST___	SP___	S-CD18						
	ST___	SP___	S-CD19						
	ST___	SP___	S-CD20						

Note: Do not measure Fern, Liana, Palm, Pandanus, Bamboo, Seedling, Coarse woody debris (<10cm), Litter

Measurement of Felling-caused Deadwoods and Residues at Felling Plot



Measurement Guidance for Residues

1) Identify stump and other associated residues first

2) Make sure to group all identified residues with same tree ID (e.g., same F-TR1 for stump, log piece, and top log)

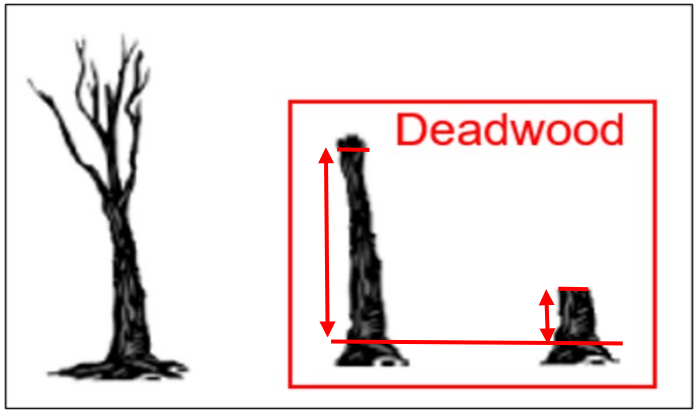
3) Measure diameters of cross sections of respective pieces with diameter tape. In case it is unmeasurable with diameter tape due to its size or shape, please measure the diameters at two points perpendicular to each other

a) Stump: Top diameter

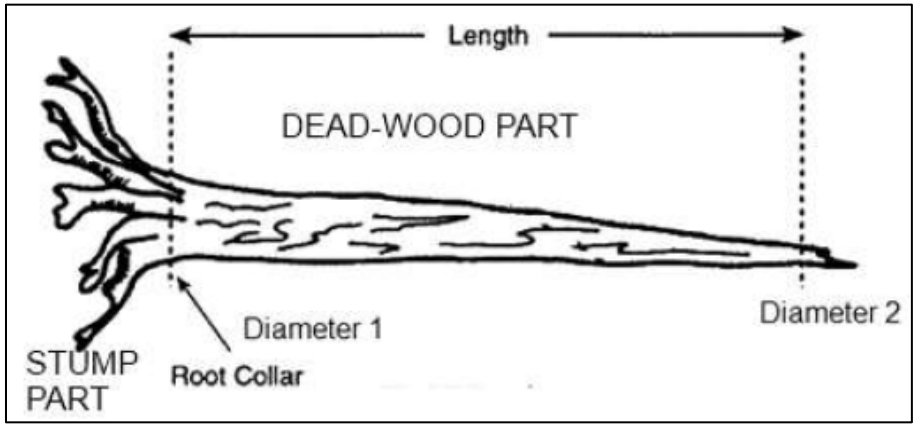
b) Log Piece: Diameters of top and bottom of piece

c) Top Log: Diameter of cross section

4) Measure length of respective residues



Standing Deadwood



Lying Deadwood

Logging Carbon Monitoring Survey

FORM 4: Felling Damage

Page 1 / _______

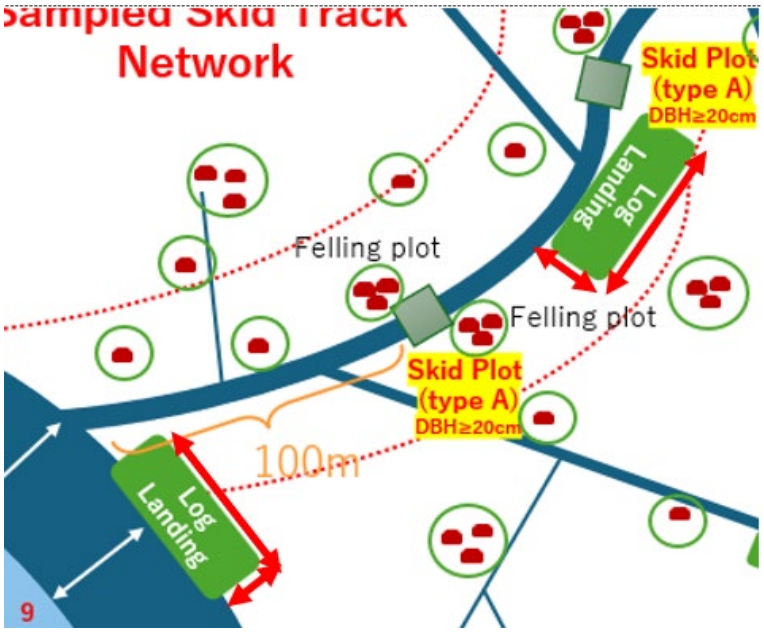
Setup ID	Skid Track No.	Felling Plot No.	Tree ID	Object Type	Form L=Lying S=Standing	Tree Species	Height / Length (m)	D1 (cm) Root Collar Diameter	D2 (cm) Trunk Top Diameter	D3 (cm) Only in case that diameter cannot be measured with	D4 (cm)	Remarks
	ST1	FP1	F-TR1									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									
	ST___	FP___	F-TR ___									

Note:

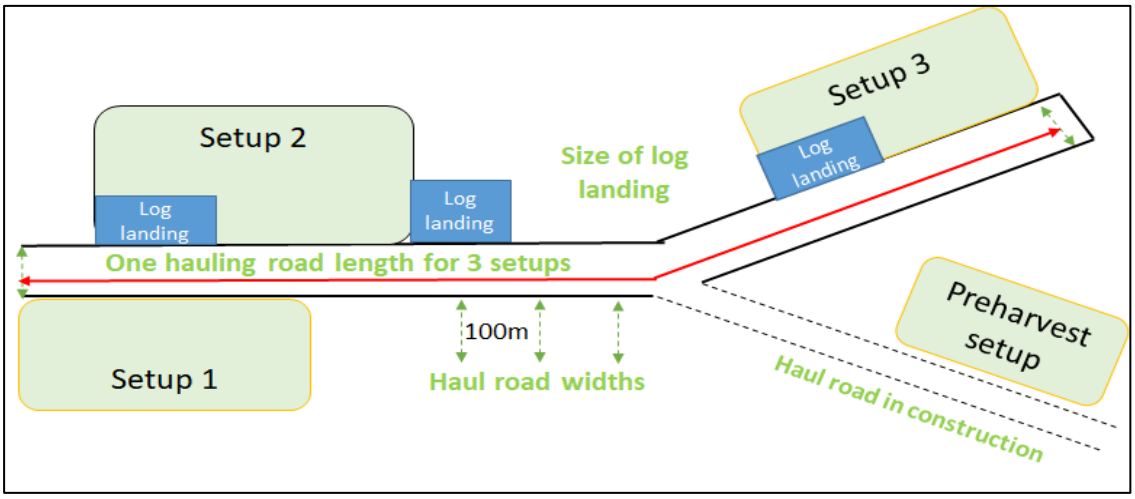
1) Object Type: Stump, Log Piece, Top Log, Abandoned Log, Deadwood (only in case of deadwood, please write its form)

2) Do not measure Fern, Liana, Palm, Pandanus, Bamboo, Seedling, Coarse woody debris (<10cm), Litter

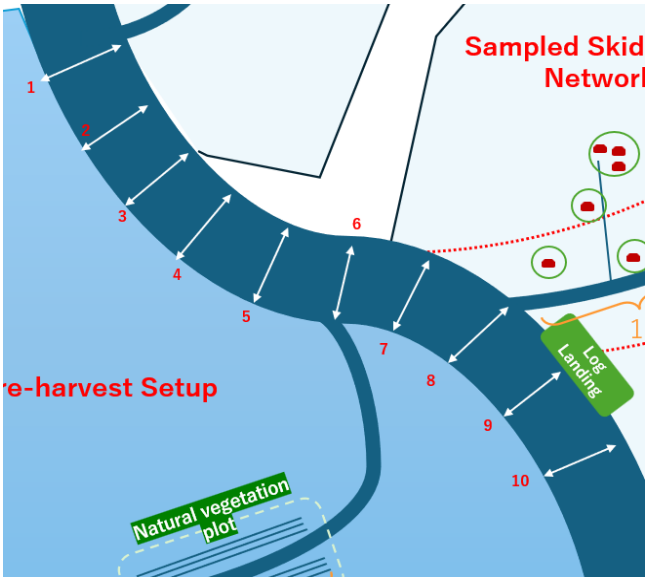
Measurement of Hauling infrastructure



Log Landing Measurement



Hauling Road Length Measurement



Hauling Road Width Measurement (10times every 10% of total length)

Logging Carbon Monitoring Survey Page ____ / _____

FORM 5: Hauling Infrastructure

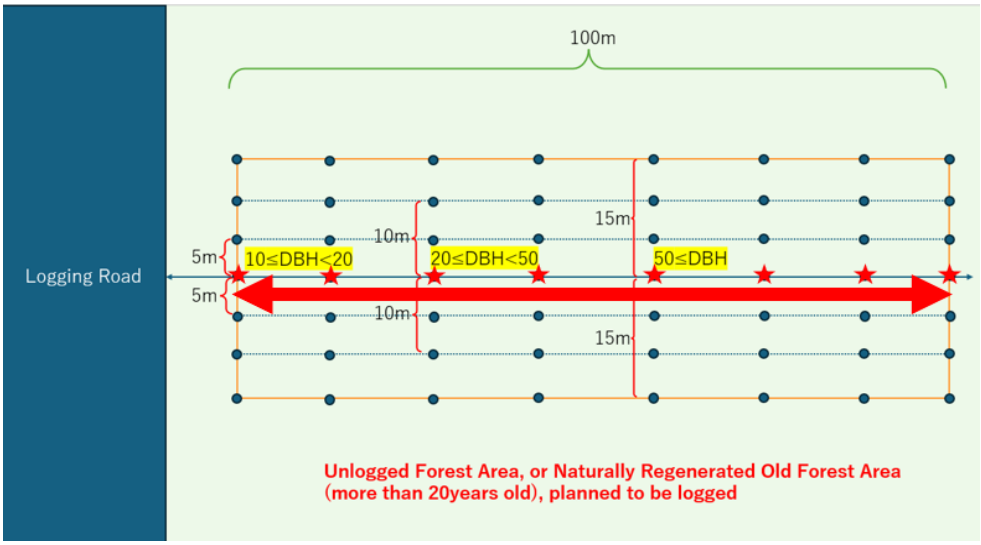
In case of measuring with tape measure

Setup ID	Log Landing No	Length (m)	Width (m)	GPS Measurement Result (ha)	Remarks
	LL 1				LL location: ST1
	LL 2				
	LL 3				
	LL 4				
	LL 5				
	LL 6				
	LL 7				
	LL 8				

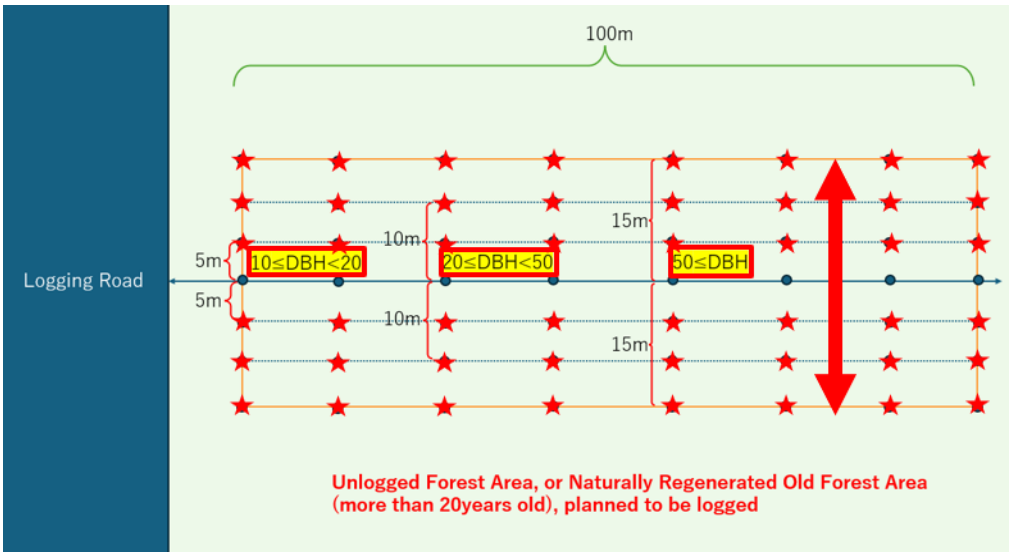
Setup ID	Hauling Road ID	Road Length (m)	Rord Width No.	Road Width (m)	No. of steups the road provides access to
	HR 1		Width 1		
			Width 2		
			Width 3		
			Width 4		
			Width 5		
			Width 6		
			Width 7		
			Width 8		
			Width 9		
			Width 10		

Memo:

Measurement of Trees at Natural Vegetation Plot



Plot Design of 100m Strip line based Rectangular Plot



DBH based Threshold for Measurement

Inventory work at Natural Vegetation Plot

Threshold	*Plot size*	*Remarks*
DBH≥50cm	**30m x 100m**	15m range at both side
20cm≤DBH<50cm	**20m x 100m**	10m range at both side
10cm≤DBH<20cm	**10m x 100m**	5m range at both side

Measurement Guide

1) Measure DBH according to threshold with diameter tape

2) Measure height **every 4th tree** and **all tree DBH>40cm** with laser range finder

3) In case that laser range finder does not work due to disturbance, you can measure angle with clinometer and distance from the tree with tape measure. Once you go back to the office, tree height can be calculated based on distance and angle.

4) For those its height is not measured, NFI's method to estimate tree height will be applied.

Logging Carbon Monitoring Survey

FORM 6: Natural Vegetation

Location *(Left/Right side of Strip line)*	***Tree ID***	***Tree Species***	***Height (m)***	***DBH (cm)***	***Remarks*** *(in case laser range finder does not work, please write angle and distance here)*
	NV-TR1				
	NV-TR2				
	NV-TR3				
	NV-TR4				
	NV-TR5				
	NV-TR6				
	NV-TR7				
	NV-TR8				
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