3.4 Verification of NFI (Cycle 4)

3.4.1 Perspective on Verification and QA/QC

(1) Objective

The timber volume used in the RELs/RLs in Vietnam's REDD+ is estimated from the results of the Vietnam National Forest Inventory (NFI). In order to verify the accuracy of this timber volume, the Study Team re-measure the site survey data from the Cycle-4 survey as a third-party organization and compare the estimated timber volume from the re-measured data with the estimated timber volume from the Cycle-4 data.

Moreover, in the process of re-measurement, the Study Team attempt to identify the factors causing error from the perspective of QA/QC (quality assurance and quality control) and recommend improvement measures. These recommendations is provided with the aim of contributing to the design of Cycle-5 in Vietnam and REDD+ project verification surveys in other countries.

Note that the re-measurement is also part of the PDCA (plan, do, check, act) cycle in the NFI. It is important in light of the results of QA/QC and timber volume verification to improve the accuracy of NFI surveys going forward. This one assessment at this point in time does not determine the accuracy of resource surveys in Vietnam.

(2) Approach of Timber Volume Verification Methods

The NFI was designed to estimate the amount of national forest resources (average timber volume by region and forest type) at each point in time. A substantial sample size is necessary in order to perform the same level of timber volume estimates in the verification survey and assess the uncertainty, but this is infeasible given the time and budgetary restrictions. The verification survey must be taken place with a smaller sample size than Cycle-4, which is the survey being verified(Figure3.4.1).

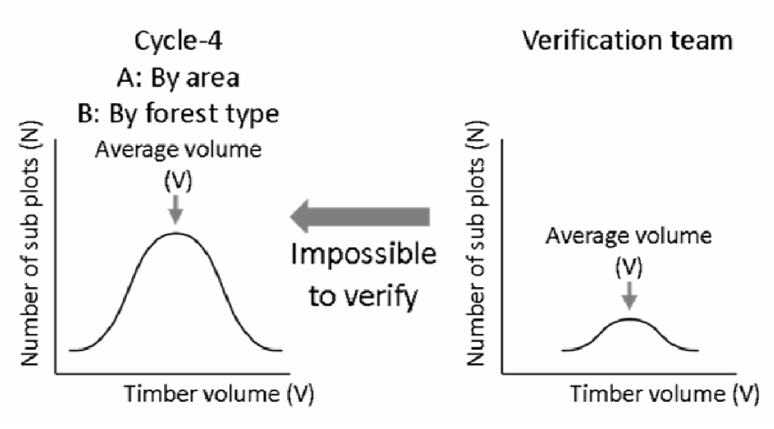


Figure 3.4.1 Image of verification

Therefore the Study Team decided to estimate the timber volume covered by the verification for each sub-plot, which are the implementation units for the tree measurement, and compare them. Performing a one-to-one comparison for each sub-plot requires that the Study team be able to re-measure the same sub-plots as those measures in Cycle-4, in other words, “repeatability” (Figure 3.4.2).

3.4.2 Re-measurement Survey Methods

(1)Selection of Re-measurement Plots

1,868 plots were surveyed in Cycle-4. Among these, the Study Team selected re-measurement plots for verification from among the 668 plots surveyed in 2009 and 2010, in order to eliminate the influence of the amount of growth as much as possible.

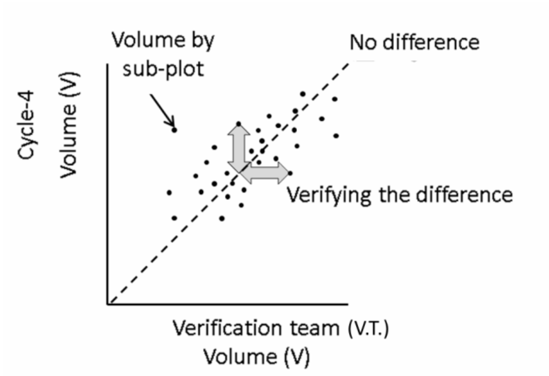


Figure 3.4.2 Image of comparison of volume

The Study Team decided to sample 26 plots that met the criteria of being in forest areas and being accessible, and to perform verification surveys on 16 sub-plots each, for a total of 416 subplots. In terms of regions, the verification survey would cover a broad range of the country, while covering four agro-Eco zones—North East, North Central Coast, South Central Coast, and Central Highlands—with consideration given to ensuring that a diverse array of forest types and other aspects are included.

The results, as shown in Section (2) Survey Implementation, were that verification surveys were performed on 388 sub-plots in 26 plots due to the effects of weather and other factors.

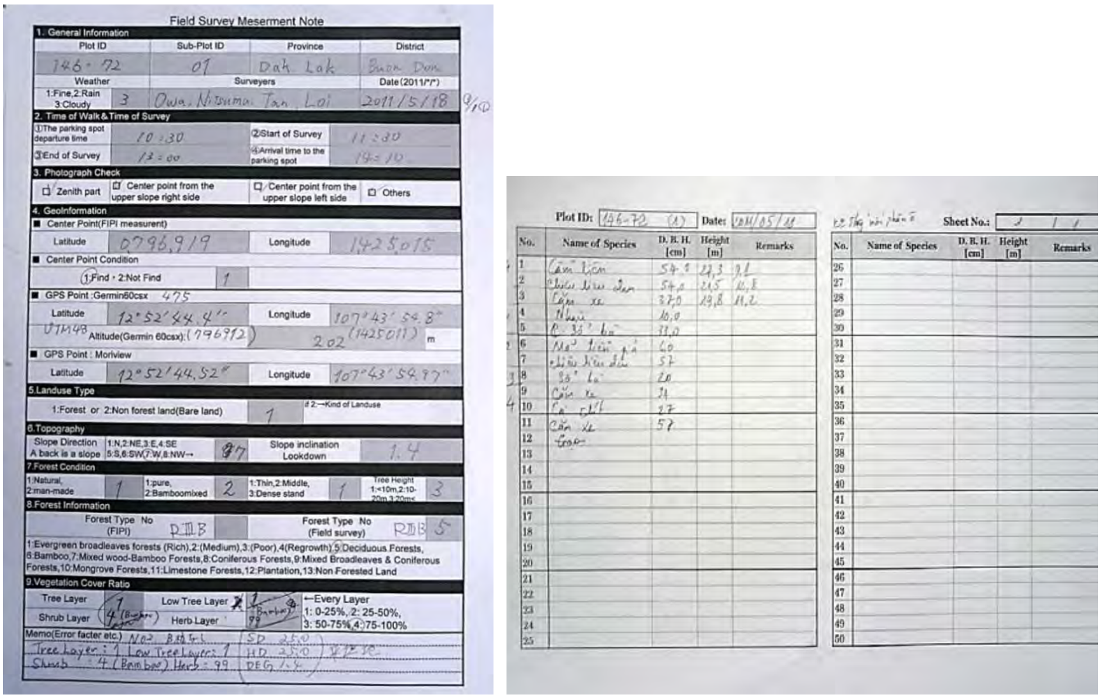
The timber volume verification covered the timber volumes in each sub-plot.

(2)Survey Items

The items surveyed in the re-measurement are as shown in the following Table 3.4.1. An example of entries in an on-site field notebook is also shown in Figure3.4.3.

Table 3.4.1 Re-Measurement Survey Items

Location of Sub-Plots	Stake GPS Coordinates and Area
Tree measurement	Tree species(local name) Diameter at breast height (1.3 m, covers 6 cm or larger, 0.1 cm units) Tree height, Bole height (three trees or more per sub-plot, 0.1 m units)
Others	Topography (orientation, slope), forest type, vegetation cover ratio Forest conditions (artificial/natural, pure/mixed forest, crown density, average tree height)


Field Survey Meserment Note

1. General Information

Plot ID	Sub-Plot ID	Province	District
146-72	01	Dak Lak	Buon Don

Weather 1:Fine,2:Rain 3:Cloudy	Surveyers	Date(2011/*/*)
3	Owa, Nitsuma, Tan, Loi	2011/5/18

2. Time of Walk & Time of Survey

①The parking spot departure time	10:30	②Start of Survey	11:30
③End of Survey	13:00	④Arrival time to the parking spot	14:10

3. Photograph Check

☑ Zenith part ☑ Center point from the upper slope right side ☐ Center point from the upper slope left side ☐ Others

4. GeoInformation

■ Center Point(FIPI measurent)

Latitude	0796919	Longitude	1425015

■ Center Point Condition

1:Find・2:Not Find | 1

■ GPS Point : Germin60csx 475

Latitude	12°52'44.4"	Longitude	107°43'54.8"
UTM48 Altitude(Germin 60csx): (796912)		202 (1425011)	m

■ GPS Point : Morlview

Latitude	12°52'44.52"	Longitude	107°43'54.97"

5. Landuse Type

1:Forest or 2:Non forest land(Bare land) | 1 | if 2→Kind of Landuse

6. Topography

Slope Direction A back is a slope	1:N,2:NE,3:E,4:SE 5:S,6:SW,7:W,8:NW→	8/7	Slope inclination Lookdown	1.4

7. Forest Condition

1:Natural, 2:man-made	1	1:pure, 2:Bamboomixed	2	1:Thin,2:Middle, 3:Dense stand	1	Tree Height 1:<10m,2:10-20m,3:20m<	3

8. Forest Information

Forest Type No (FIPI)	PIIB	Forest Type No (Field survey)	PIIB 5

1:Evergreen broadleaves forests (Rich),2:(Medium),3:(Poor),4:(Regrowth),5:Deciduous Forests, 6:Bamboo,7:Mixed wood-Bamboo Forests,8:Coniferous Forests,9:Mixed Broadleaves & Coniferous Forests,10:Mongrove Forests,11:Limestone Forests,12:Plantation,13:Non Forested Land

9. Vegetation Cover Ratio

Tree Layer	1	Low Tree Layer	1	←Every Layer 1: 0-25%, 2: 25-50%, 3: 50-75%, 4: 75-100%
Shrub Layer	4 (Bamboo)	Herb Layer	99	

Memo(Error factor etc.)

Tree Layer : 1 Low Tree Layer : 1 SD 25.0

Shrub : 4 (Bamboo) Herb : 99 HD 25.0 DEG 1.4

No.	Name of Species	D.B.H. [cm]	Height [m]	Remarks
1	Cẩm liên	54.1	22.3	9.1
2		54.0	21.5	11.8
3	Cẩm xe	37.0	19.8	11.2
4		10.0		
5		11.0		
6		60		
7		57		
8		20		
9	Cẩm xe	21		
10		27		
11	Cẩm xe	57		
12				
13–25				

Plot ID: 146-72 (1) Date: 2011/05/18 Sheet No.: 1/1

No.	Name of Species	D.B.H. [cm]	Height [m]	Remarks
26–50				

Figure 3.4.3 Examples of on-site field notebook entries

(3) Plot Setting

A single plot spans 2 km in all four directions from stake A. In the plot, 20 sub-plots (20 m × 25 m) are lined up from stake A in the northward and eastward directions (Figure 3.4.4 and Figure3.4.5). The Study Team attempted to repeat these sub-plots in the re-measurements.

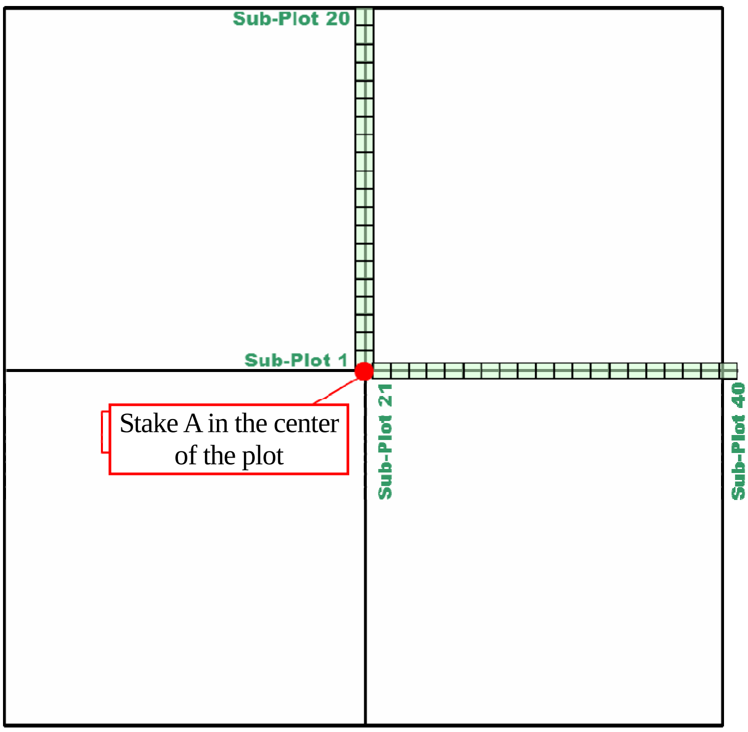


Figure 3.4.4 Plot

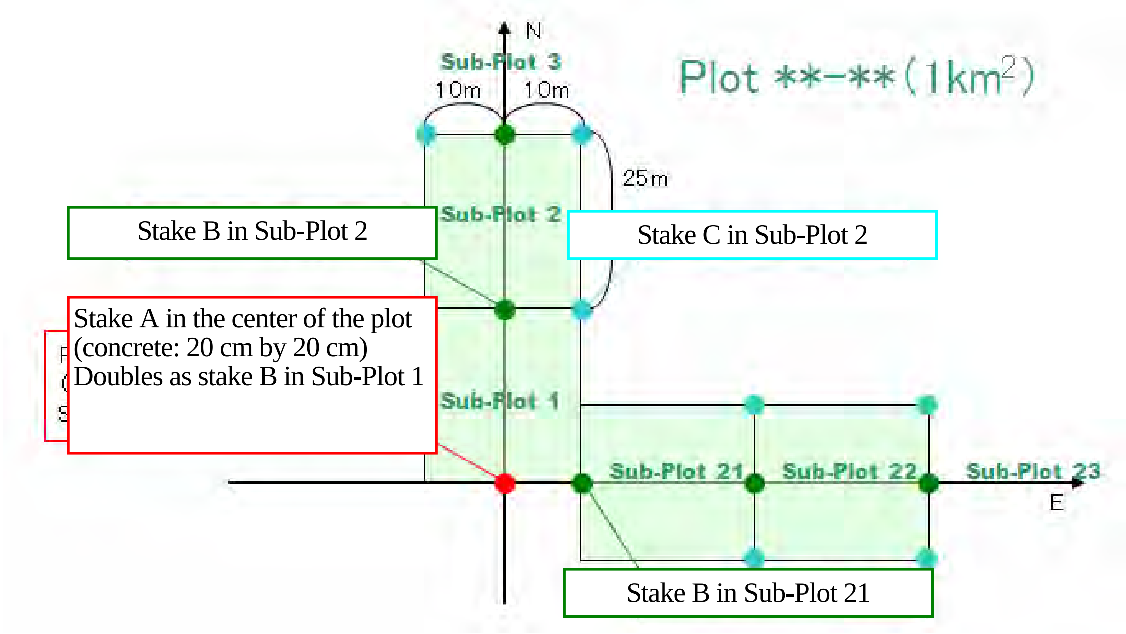


Figure 3.4.5 Detail view of the center of a plot

(4)Survey Implementation

The provinces in which the Study Team conducted the verification survey are as shown the map in Figure3.4.6 and Table 3.4.2. The four agro-Eco zones covered were North East, North Central Coast, South Central Coast, and Central Highlands.

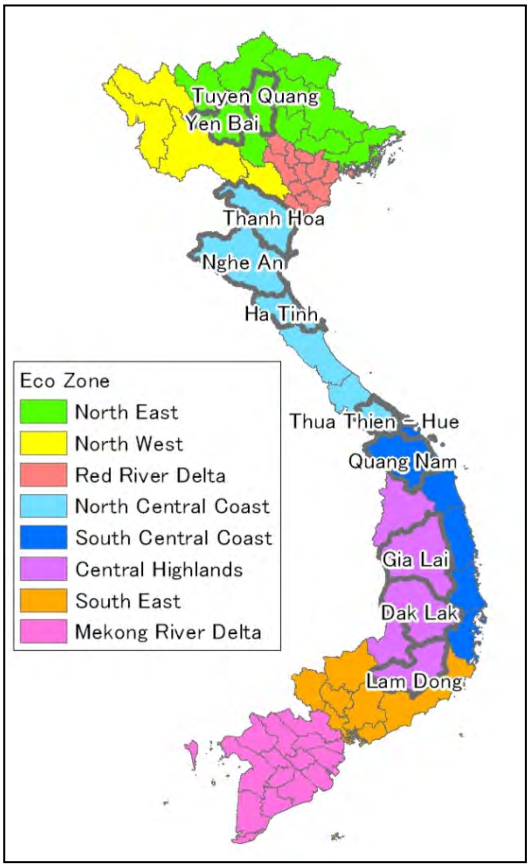


Figure 3.4.6 The provinces in which the Study Team conducted the on-site verification survey and agro-Eco zones

Table 3.4.2 No. of On-Site Survey Implementation Sub-Plots

Agro-Eco zone	Province	Plot ID	No. of Sub-Plots	Cycle-4 Survey Year
North East	Tuyen Quang	19-37	24	2009
		22-41	18	2010
		Total	42	
	Yen Bai	24-34	15	2009
		25-34	15	2009
		28-33	9	2010
		Total	39	
	Total		81	
North Central Coast	Thanh Hoa	48-39	19	2009
		Total	19	
	Nghe An	59-29	13	2009
		63-37	19	2010
		66-41	16	2010
		Total	48	
	Ha Tinh	74-46	21	2009
		74-51	16	2009
		Total	37	
	Thua Thien Hue	101-71	13	2010
		400-67	21	2009
		401-69	12	2010
		401-71	17	2010
		Total	62	
	Total		167	
South Central Coast	Quang Nam	107-71	16	2009
		108-69	7	2009
	Total		23	
Central Highlands	Gia Lai	133-81	10	2009
		Total	10	
	Dak Lak	146-72	5	2009
		148-84	16	2009
		150-83	9	2010
		154-76	10	2009
		Total	40	
	Lam Dong	157-82	18	2009
		157-83	16	2009
		159-83	16	2009
		162-74	17	2009
		Total	67	
	Total		117	
Grand total		26	388	

The number of sub-plots for which verification surveys were conducted divided between natural forests and plantation is as shown in the Table 3.4.3.

Table 3.4.3 No. of Verification Survey Implementation Sub-Plots by Forest Type

Agro-Eco zone	Province	Forest			Non-Forested Land	Grand Total
		Natural Forest	Plantation	Forest Total		
North East	Tuyen Quang	5	11	16	26	42
	Yen Bai	8	26	34	5	39
	Total	13	37	50	31	81
North Central Coast	Thanh Hoa	16	0	16	3	19
	Nghe An	22	25	47	1	48
	Ha Tinh	3	32	35	2	37
	Thua Thien Hue	22	21	43	20	63
	Total	63	78	141	26	167
South Central Coast	Quang Nam	20	2	22	1	23
Central Highlands	Gia Lai	10	0	10	0	10
	Dak Lak	12	2	14	26	40
	Lam Dong	50	0	50	17	67
	Total	72	2	74	43	117
Grand total		168	119	287	101	388

3.4.3 QA/QC Based on Re-Measurement

(1)Problems in Repeatability

In performing re-measurements for this verification survey, there was a problem with low repeatability due to the difference in survey years between Cycle-4 and the verification survey, as well as the difficulty in identifying sub-plots and individual trees.

The re-measuring in the verification survey was performed in 2011, one to two years after the Cycle-4 survey was performed in 2009 and 2010. For this reason, although the minimum measured diameter in Cycle-4 was 6 cm, in the re-measurement results the Study Team set the minimum to 8 cm or higher for the trees subject to comparison, in consideration of the amount of growth (even in the re-measurement, the minimum measured diameter was 6 cm).

As shown in Figure 3.4.7, in cases where the trees were not measured in Cycle-4 even if it was 8 cm or taller upon re-measurement, it is not discernible whether these trees were overlooked in Cycle-4 or whether they were left out of the Cycle-4 measurements because they were under 6 cm. This means that the repeatability is veritably reduced by the difference in survey years between Cycle-4 and the re-measurement.

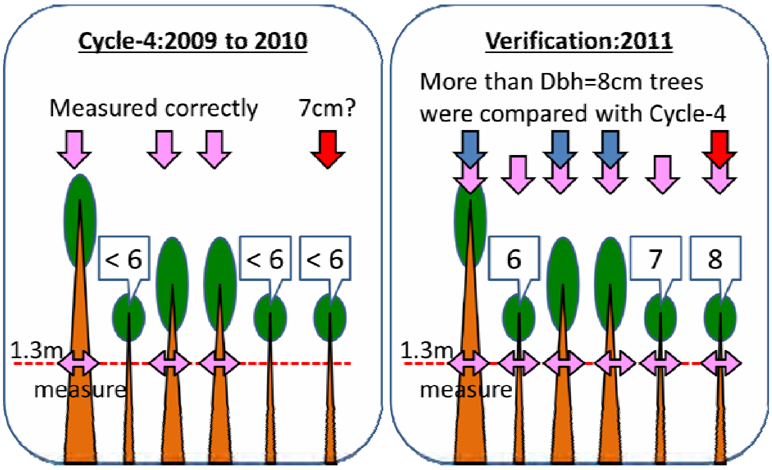


Figure 3.4.7 Examples of reduced repeatability due to the different in survey years

The only cases in which re-measurement could be performed with the same scope as Cycle-4 are those in which stake B in sub-plot *n* and stake B in sub-plot *n*+1 (the next sub-plot) could be identified at the time of re-measurement. As mentioned later, the percentage of stake B's identification was in fact low, which resulted in a low level of repeatability for the sub-plots.

Furthermore, since the trees that were measured in Cycle-4 are not numbered or otherwise tagged, the Study Team could not compare the measured values for individual trees upon re-measurement. For diameters, instead of comparing the diameters of individual trees, the Study Team were forced to compare the total basal area for each sub-plot.

In evaluating the verification results, it must be kept in mind that the re-measuring was being conducted amid the conditions of low repeatability described above.

(2)Different Equipment between the Study Team and Cycle-4

According to the hearings from accompanied officers of Sub-FIPI, measurement item used for Cycle-4 is summarized as in below Table 3.4.4 and Figure 3.4.8.

Table 3.4.4 Measurement Item of Cycle-4 and the Study Team

Measurement Item	Cycle-4	The Study Team
Plot setting	Horizontal distance was measured by keeping the measuring tape horizontal by eye. Slope distance conversion tables were not used.	Vertex was used for horizontal distance.
	Orientation was determined by compass.	Orientation was determined by compass glass.
Diameter at breast height	Measuring tape was used. It was later divided by 3.14.	A diameter measure was used.
Tree height	Blume-Leiss, Sunto (Figure3.4.8)	Vertex, TruPulse

Blume-Leiss Suunto

Figure 3.4.8 Measurement item of Cycle-4

(3)Verification regarding Plot Setting

1) Plot Location

As shown in Table 3.4.5, The stake A used for identifying plot position was found for 24 of the 26 plots (sub-plot No. 1). The stake A's are made of concrete and show the plot number and surveyed cycle number on top (Figure 3.4.9). The cycle number is overwritten if the same plot is surveyed twice.

The two plots that could not be confirmed because the stakes were extracted from the ground or moved from the original point plantation by local residents (they could have been moved during intentional burning in areas where coffee plantations were expanding, or removed by children when searching for bamboo shoots), but they were identified because of the stake holes left behind, since local residents who had assisted with Cycle-4 or counterparts who had performed Sub-FIPI recognized the location of the stakes.

Table 3.4.5 Stake A Confirmation Status

Presence of Stake A	Forest			Non-Forested Land	Grand Total
	Natural Forest	Plantation	Forest Total		
With stake	10	6	16	8	24
Without stake	1	0	1	1	2
Grand total	11	6	17	9	26

Stake A

Remnant of removed stake (confirmation of hole)

Figure 3.4.9 Stake A

2) Sub-Plot Location

As shown in Table 3.4.6, there were many cases where stake B could not be found in order to identify the sub-plots, with 44% being confirmed in natural forests and 21% in plantation.

Stake B is made of wood (some use small tree) and marked with red paint, and although they remained in plantation if people had not been in the area after the survey, most of the plantation were fast-growing tree species so stake B remained in a low percentage of cases due to repeated logging, burning, and replanting over several years. Even in natural forests, there were cases where the high temperature and humidity caused the stakes to decay and disappear(Figure3.4.10).

Table 3.4.6 Stake B Confirmation Status

Presence of Stake B	Forest			Non-Forested Land	Grand Total
	Natural Forest	Plantation	Forest Total		
With stake	69	24	93	12	105
Without stake	88	89	177	80	257
Grand total	157	113	270	92	362

Note: These are sub-plots besides sub-plot No. 1 (No. 1 was confirmed with stake A).

Plantation (newly planted) in which no stake B could be confirmed

Stake B remaining in natural forest

Stake B remaining in plantation and conditions in the forest

Figure 3.4.10 Stake B

As explained above, stake A made of concrete, which identifies the plot, remained in a high percentage of cases, while stake B made of wood, which identifies the sub-plots, remained in a low percentage of cases. The confirmation status of stake A and stake B combines is given in the following Table 3.4.7.

Table 3.4.7 Confirmation Status of Stake A and Stake B

Presence of Stake A and Stake B	Forest			Non-Forested Land	Grand Total
	Natural Forest	Plantation	Forest Total		
With stake	79	30	109	20	129
Without stake	89	89	178	81	259
Grand total	168	119	287	101	388

In cases where stake B could be identified, errors in the location of the sub-plots due to mismatches in the horizontal distance or direction were confirmed. Based on this, if stake B could not be identified, there were cases where the position of the sub-plot was not accurately repeated (analyzed in detail in the next sub-section). In topography that has many undulations, mismatches for one sub-plot judging from the land use classification when proceeding seven to eight sub-plots from stake A—that is, mismatches of 25 m or more—arose.

Disparities in the locations of sub-plots due to mismatches in direction were also confirmed. With a compass, the instrument's individual variability and reading method can change the result by several degrees. If the direction is off by one degree, it would translate into a mismatch of 8.7 m sideways in proceeding 500 m through sub-plot 20.

If the transect goes over a road or river, it was sometimes not repeatable because it was not clear how to proceed at that time.

The location of stake B for sub-plot 21 in the eastward direction should have been 10 m east of stake A, but there were cases where it was estimated that sub-plot 21 was started from stake A. In such cases, sub-plot 1 would overlap with sub-plot 21.

Given error factors such as the above, when stake B cannot be found, the farther away from stake A the greater the mismatch between the plots set in the verification survey and the plots in Cycle-4.

3) Sub-Plot Size

Sub-plots for which the measured valued from the Study Team and Cycle-4 can be compared are limited to those in which stake B in sub-plot *n* and stake B in sub-plot *n*+1 (the next sub-plot) were identified upon re-measurement. There were 80 sub-plots that met this condition. The Study Team measured the horizontal distance between stake B's using Vertex and compared this with the sub-plots' designed horizontal distance of 25 m. Note that the slope was measured as the slope in the length-wise direction of the sub-plot (direction of the transect).

Here, "sub-plot horizontal distance error" = "distance between stake B's measured in the verification survey" – "25 m", and "sub-plot horizontal distance error rate" = "absolute value of sub-plot horizontal distance error" / "25 m".

As shown in Figure 3.4.11, Figure 3.4.12 and Table 3.4.8, Table 3.4.9, when the slope exceed 30 degrees, the error tends to increase.

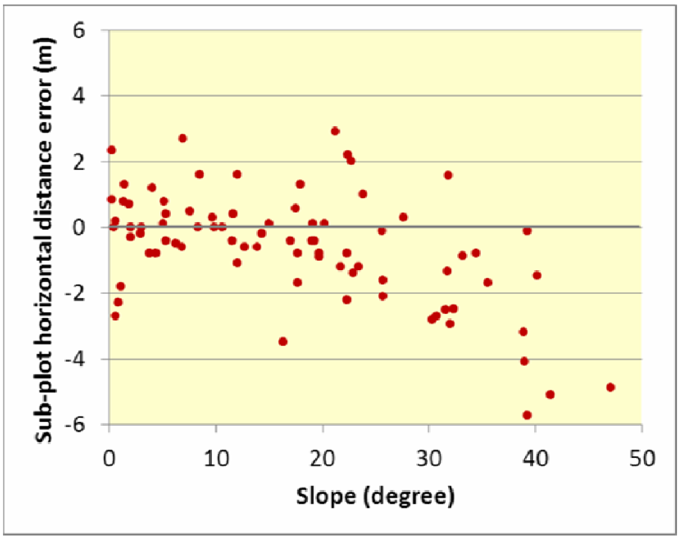


Figure 3.4.11 Sub-plot horizontal distance error and slope

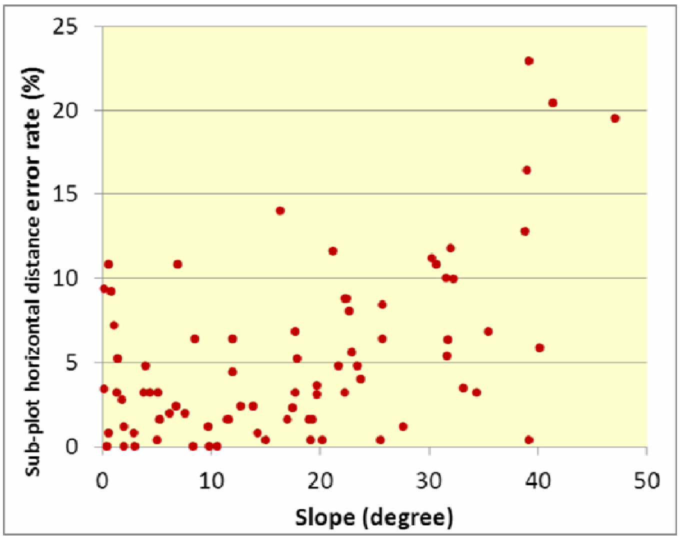


Figure 3.4.12 Sub-plot horizontal distance error rate and slope

Table 3.4.8 Sub-Plot Horizontal Distance Error Statistics

Slope	Average (m)	Standard Deviation (m)	Maximum (m)	Minimum (m)	Data Points
Under 30°	-0.1	1.3	2.9	-3.5	63
30° or more	-2.4	1.8	1.6	-5.7	17
Grand total	-0.6	1.7	2.9	-5.7	80

Table 3.4.9 Sub-Plot Horizontal Distance Error Rate Statistics

Slope	Average (%)	Standard Deviation (%)	Maximum (%)	Minimum (%)	Data Points
Under 30°	3.8	3.4	14.0	0.0	63
30° or more	10.4	6.2	22.9	0.4	17
Grand total	5.2	5.0	22.9	0.0	80

(4)Verification regarding Tree Measurement

1) Number of Trees Subject to Measurement

As indicated in Section (1)Problems in Repeatability, the trees were only subject to verification if stake B in sub-plot *n* and stake B in sub-plot *n*+1 were identified during re-measurement and if the same scope as Cycle-4 could be re-measured. Also, during the period of time from the year in which Cycle-4 was implemented and the time of re-measuring for the verification survey, in order to remove the influence of in-growth trees grown up to a size subject to measurement from having been under 6 cm in diameter at breast height and not subject to measurement, to the extent possible we compared the number of trees with a diameter at breast height of at least 8 cm from among the trees measured in the verification survey with the number of trees measured in Cycle-4.
There were 67 sub-plots for which comparisons could be made under both conditions.

A comparison of plantation with natural forests and a comparison of Cycle-4 survey implementation years, respectively, are shown in Figure3.4.13, Figure3.4.14. The basic statistics by forest type are shown in the Table 3.4.10, Table 3.4.11.
Here, “error in number of trees measured” = “number of trees measured in Cycle-4” – “number of trees measured in verification survey (8 cm or larger)”, and “error rate in the number of trees measured” = “absolute value of error in number of trees measured” / “number of trees measures in verification survey (8 cm or larger)”.

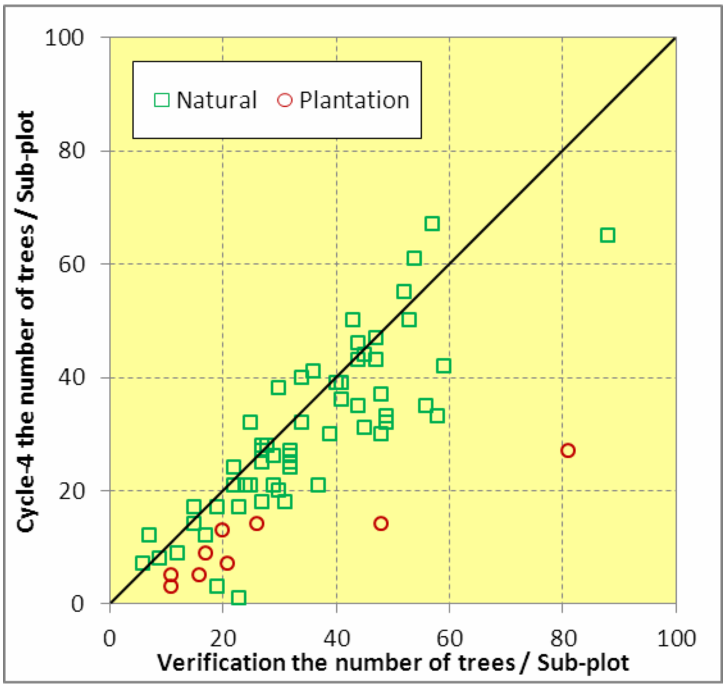


Figure 3.4.13 Comparison of number of trees measured by forest type

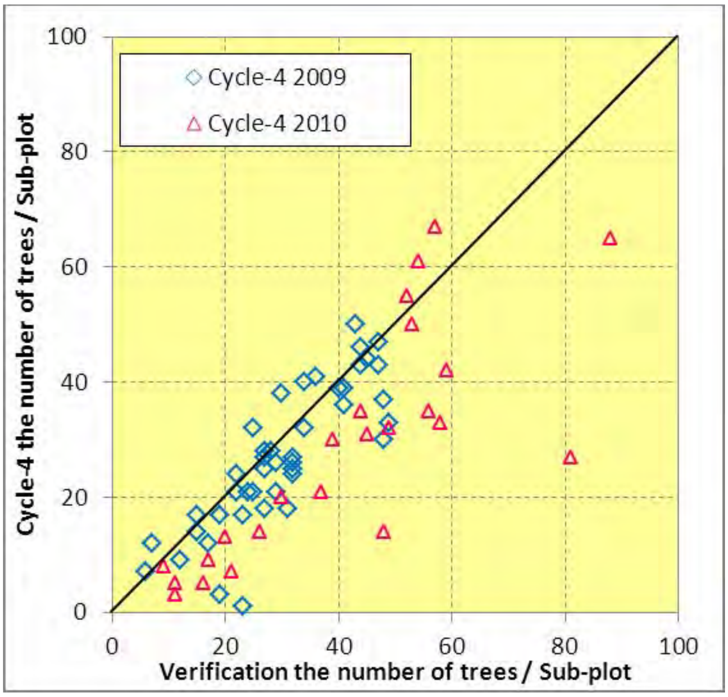


Figure 3.4.14 Comparison of number of trees measured in the implementation years of Cycle-4

Table 3.4.10 Error Statistics on the Number of Trees Measured

Forest Type	Average (No. of Trees)	Standard Deviation (No. of Trees)	Maximum (No. of Trees)	Minimum (No. of Trees)	Data Points
Natural forest	-5	8	10	-25	58
Plantation	-18	16	-6	-54	9
Grand total	-7	11	10	-54	67

Table 3.4.11 Error Rate Statistics on the Number of Trees Measured

Slope	Average (%)	Standard Deviation (%)	Maximum (%)	Minimum (%)	Data Points
Natural forest	21.4	18.9	95.7	0.0	58
Plantation	60.4	14.7	81.8	35.0	9
Grand total	26.6	22.7	95.7	0.0	67

There is a visible trend in plantation that the number of trees measured in Cycle-4 was less than in the verification survey. Comparing by survey implementation years, Cycle-4 implemented in 2010 tended to measure a lower number of trees than the verification survey. One would expect that since the implementation in 2010 would show less of a difference with the re-measured values due to growth of the trees that it would match the verification survey, and that if it was implemented in 2009 the additional growth would result in a larger difference with the verification survey. The fact that the opposite result was obtained seems to indicated that there was a strong tendency originally for Cycle-4 to under-measure, and that the surveys done in 2009 more closely aligned with the verification survey thanks to the additional growth.

A factor contributing to the low number of trees measured in Cycle-4, or why there are gaps in the survey, is that the trees that had been surveyed in Cycle-4 were not marked. To prevent gaps in the survey it is at a minimum necessary to mark the trees with chalk or similar indicators. Trees near the borders of sub-plots are especially likely to be missed.

Moreover, in some cases the broadleaf large-diameter trees in bamboo forests and the natural trees in plantation were not measured in Cycle-4. It was a survey performed from the perspective of timber volume utilization by the forestry, so it did not measure tree species that did not fit into the relevant forest types. The surveyors need to be aware of the fact that the measurements are not of usable timber volume but of biomass.

2) Basal Area

Since there were no markings on the trees, it is impossible to compare Cycle-4 measurements with those of the verification survey for individual trees. Therefore the Study Team compared the basal area for individual sub-plots.

As with comparing the number of trees measured, the verification survey basal area for sub-plots is calculated for which two stake B's were confirmed from the trees with a diameter of 8 cm or greater at breast height. There were 67 sub-plots for which comparisons could be made under both conditions.

A comparison of natural forests with plantation and a comparison of Cycle-4 survey implementation years, respectively, are shown in Figure3.4.15, Figure3.4.16. The basic statistics by forest type are shown in Table 3.4.12, Table 3.4.13.

Here, "basal area error" = "Cycle-4 basal area" – "verification survey basal area(8 cm or larger)", and "basal area error rate" = "absolute value of basal area error" / " verification survey basal area (8 cm or larger)".

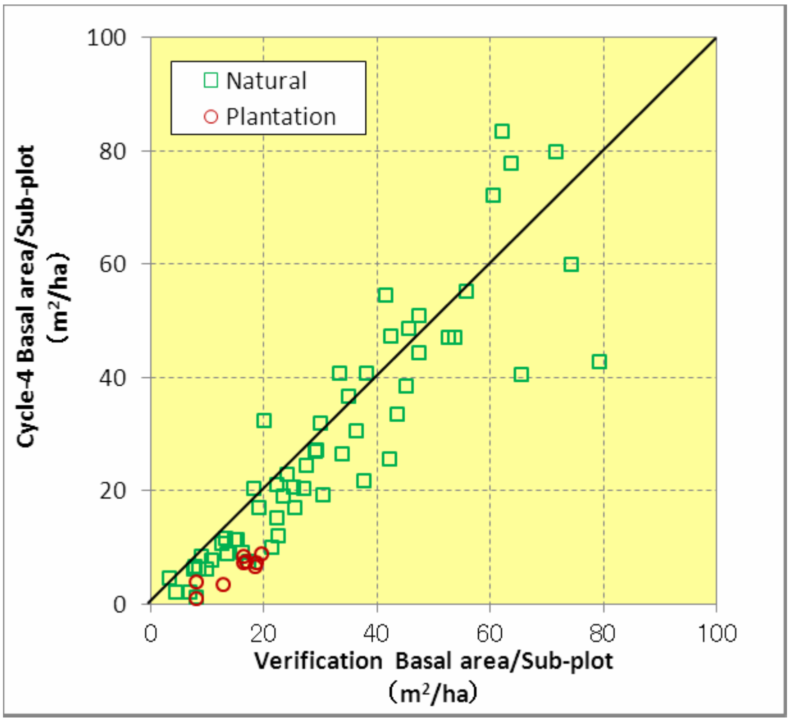


Figure 3.4.15 Comparison of basal area by forest type

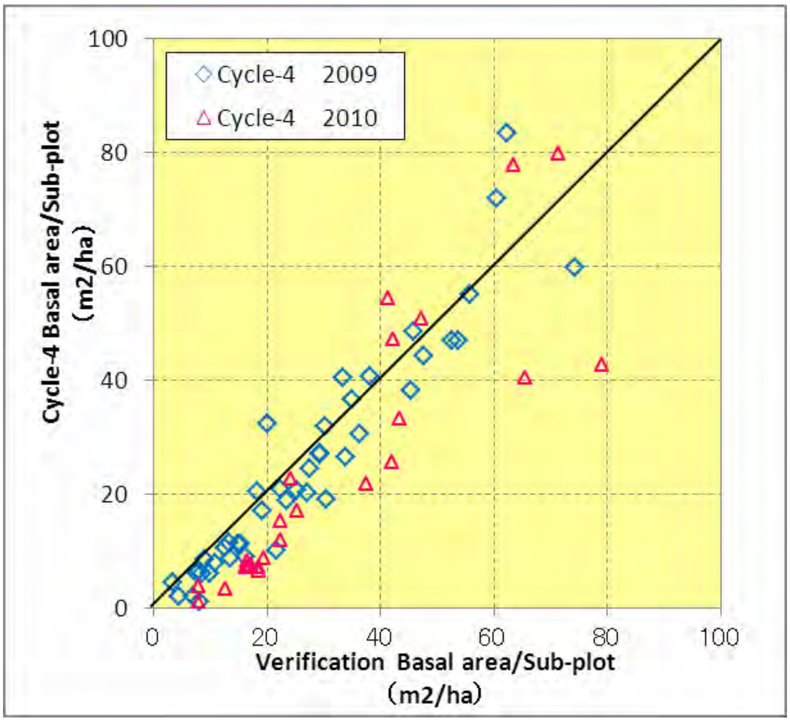


Figure 3.4.16 Comparison of basal area by year of Cycle-4 implementation

Table 3.4.12 Basal Area Error Statistics

Forest Type	Average (m^2/ha)	Standard Deviation (m^2/ha)	Maximum (m^2/ha)	Minimum (m^2/ha)	Data Points
Natural forest	-3.3	9.0	21.2	-36.7	58
Plantation	-9.2	2.3	-4.4	-12.2	9
Grand total	-4.1	8.6	21.2	-36.7	67

Table 3.4.13 Basal Area Error Rate Statistics

Slope	Average (%)	Standard Deviation (%)	Maximum (%)	Minimum (%)	Data Points
Natural forest	25.5	18.1	87.1	1.3	58
Plantation	62.5	11.4	88.6	50.0	9
Grand total	30.4	21.5	88.6	1.3	67

As with the number of trees measured, there is a visible trend in plantation that the basal area in the verification survey was greater than in Cycle-4. Comparing by survey implementation years, the verification survey's basal area tended to be higher than Cycle-4 of 2010, but showed little difference that of 2009. This could be because Cycle-4 has in inherent tendency to under-measure, hence the growth since 2009 has reduced the difference compared with the verification survey. However, since plantation growth quickly, it could also be that the influence of in-growth has not yet been fully expunged from the verification survey coverage, which is of trees of diameter 8 cm or greater at breast height.

Factors that may have contributed to the low basal area in Cycle-4 include the fact that in Cycle-4 the diameter is measured from a higher position than breast height (1.3 m)(Figure 3.4.17), there were gaps in the survey, and the survey did not measure tree species that do not fit into the relevant forest types.

The following cases were confirmed as points of caution.

- The minimum measured diameter was 6 cm, but there were plots on which the smallest tree was 8 cm.
- It is difficult to measure diameter at breast height accurately for trees that have sprouted a buttress root.
- There were plots in which the breast height position was shaved off and marked with paint. At the time of re-measurement the wounds had expanded, which can cause error in the diameter at breast height. Marking methods that inflict wounds on the plant should be avoided.

3) Tree Height

Since there were no markings on the trees, it is impossible to compare Cycle-4 measurements with those of the verification survey for individual trees. Therefore the Study Team compare tree height curve in the sub-section for timber volume verification.

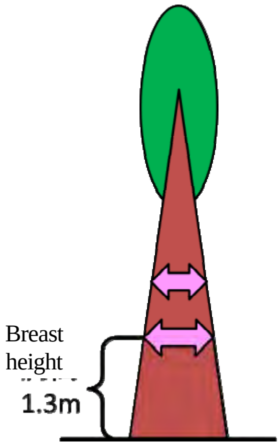


Figure 3.4.17 Error due to differences in breast height

4) Other Observations

It was apparent that the Sub-FIPI officers were enthusiastic about the survey (they were also interested in the instruments used by the verification survey team) and were seasoned in forest surveys. It was also apparent from the handwritten field notes that Cycle-4 was implemented with care. However, disparities in the horizontal distance and slope distance, the starting position of sub-plots in the eastward direction, and other misreading of the manual were noted.

(5)Timber Volume Verification

1) Timber Volume Estimation Methods

Comparison of timber volume was performed only in sub-plots that were of natural forest and confirmed to have stake B. The high growth in plantation made it difficult to make comparisons in this past verification survey, given the one to two years since the survey was implemented. Furthermore, as in the number of trees subject to measurement, although it is desirable that stake B in sub-plot *n* and stake B in sub-plot *n*+1 (the next sub-plot) be identified at the time of re-measurement and only be included if the same scope as Cycle-4 can be re-measured, the Study Team decided to allow that only stake B in sub-plot *n* be identified since the restricting the requirement to natural forests would leave too few sub-plots covered.

The verification survey timber volume is calculated from the trees with a diameter of 8 cm or greater at breast height.

There were 75 sub-plots for which comparisons could be made under both conditions.

2) Cycle-4

Timber volume estimation methods in Cycle-4 involved estimates of tree height and timber volume of individual trees, as in Figure3.4.18, and derives the average timber volume by forest type. The tree height estimation method is derived from the tree height curve for each forest type for natural forests and from the average tree height measurements for each sub-plot for plantation. The timber volume of individual trees is estimated based on timber volume tables for natural forests and the timber volume formula for plantation.

The timber volume compared with the verification survey is the sub-plot timber volume as a total of the timber volume of individual trees totaled for each sub-plot.

However, the final result of Cycle-4, the average timber volume by forest type and agro-Eco zone, has not yet been officially released by the government of Vietnam.

Note: Timber volume is not calculated for sub-plots on non-forested land. The definition of "non-forested land" in Cycle-4 is land with a crown density of less than 10%.

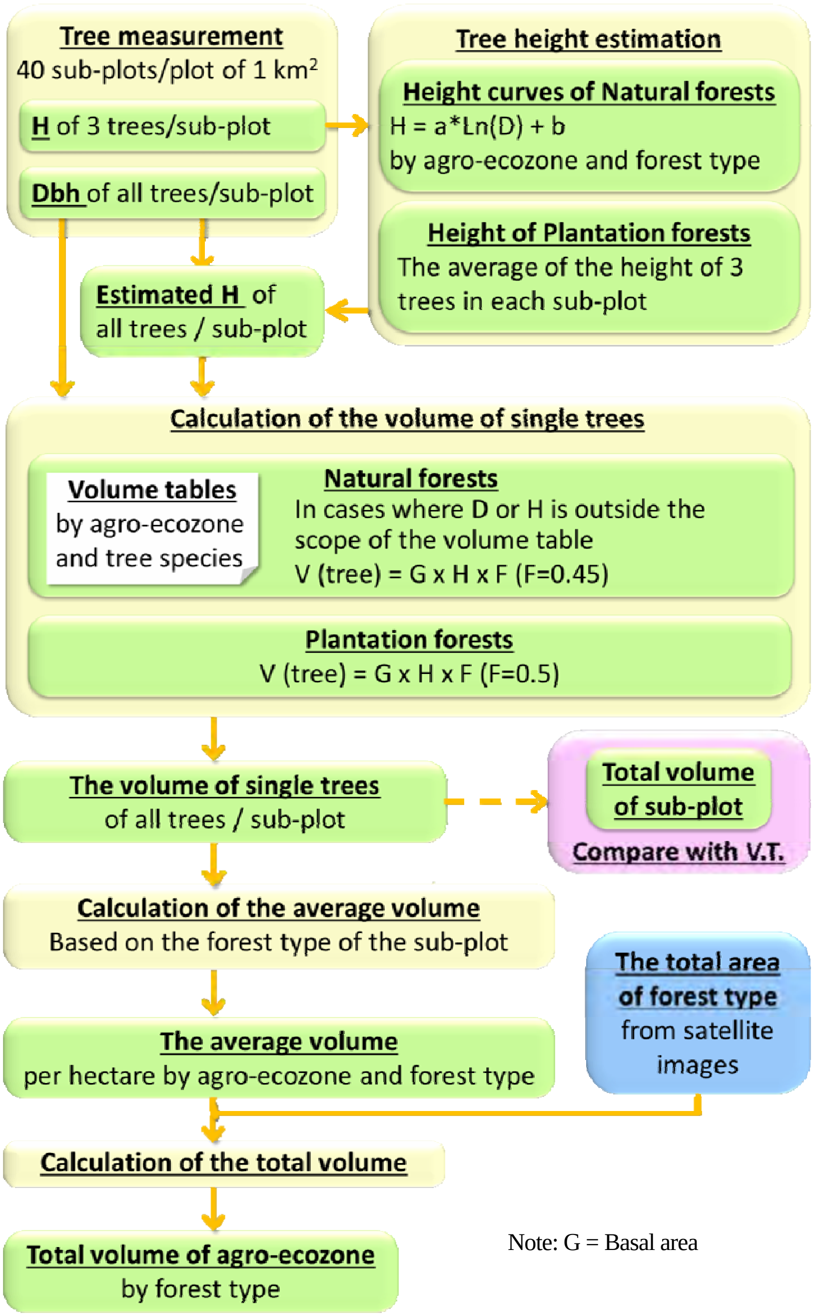


Figure 3.4.18 Timber volume estimation method in Cycle-4

3) Verification Survey

Timber volume estimation in the verification survey was performed by a fundamentally similar method to that of Cycle-4, as shown in Figure 3.4.19.

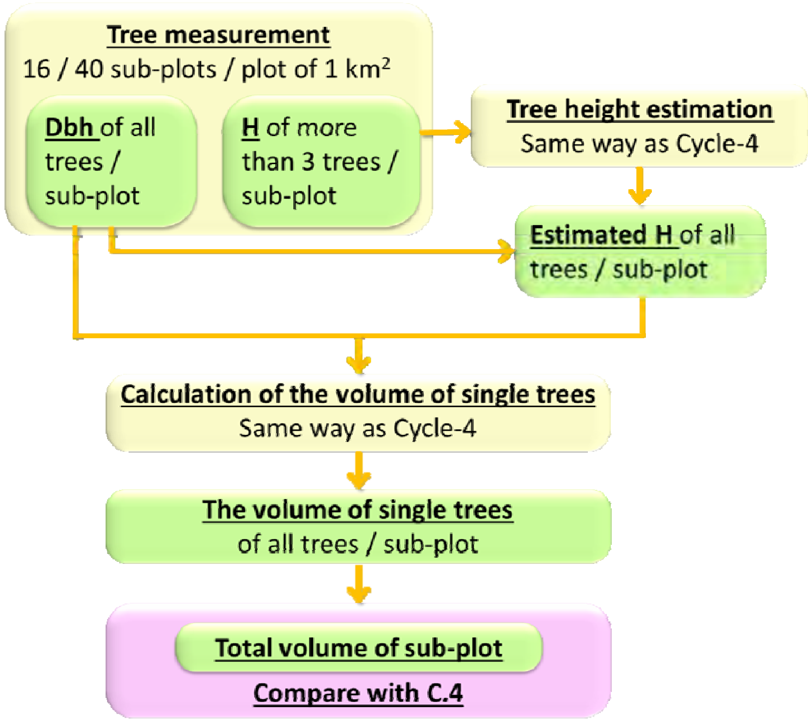


Figure 3.4.19 Timber volume estimation method in the verification survey

4) Tree Height Curve

In estimating the timber volume of a natural forest, the tree height curve used in Cycle-4 and the tree height curved used in the verification survey are each shown in Table 3.4.14. In the verification survey, the correlation of the tree height curve of 5: Central Highlands evergreen broadleaf forests is low at R(Correlation coefficient) = 0.48, but this tree height curve was used for the timber volume estimation.

Table 3.4.14 Tree Height Curve Used in Natural Forest Timber Volume Estimation

	Agro-Eco zone / Forest Type	Tree Height Curve (Upper Line: Cycle-4; Lower Line: Verification Survey)	R
1	North East Mixed Wood and Bamboo forest	H = 5.6503Ln(D) - 4.1437 H = 5.3709ln(D) - 3.3451	0.78 0.78
2	North Central Coast Evergreen - Broadleaf forest	H = 7.306Ln(D1.3) - 7.1837 H = 9.1584ln(D) - 11.865	0.79 0.85
3	North Central Coast Mixed Wood and Bamboo forest	H = 7.184Ln(D) - 6.4022 H = 6.9505ln(D) - 6.6544	0.81 0.80
4	South Central Coast Evergreen - Broadleaf forest	H = 7.1395Ln(D) - 6.8799 H = 9.1584ln(D) - 11.865	0.83 0.85
5	Central Highlands Evergreen - Broadleaf forest	H = 6.6674Ln(D) - 4.7298 H = 3.8863ln(D) + 0.3759	0.80 0.48
6	Central Highlands Deciduous forest	H = 6.0039Ln(D) - 5.4157 H = 7.2433ln(D) - 9.7218	0.73 0.84
7	Central Highlands Coniferous forest	H = 8.3474Ln(D) - 9.7238 H = 10.455ln(D) - 15.63	0.78 0.90

The respective tree height curves are as shown in the following graphs Figure3.4.20 to Figure3.4.26. The red circles represent the trees measured in the verification survey, the red line represents the tree height curve fitted to those data, and the green line represents the tree height curve used in Cycle-4.

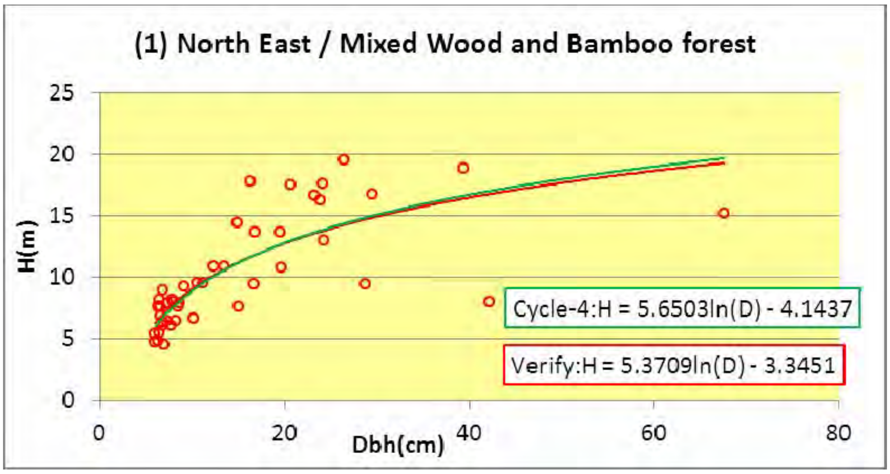


Figure 3.4.20 North East Region / mixed wood and bamboo forest tree height curve

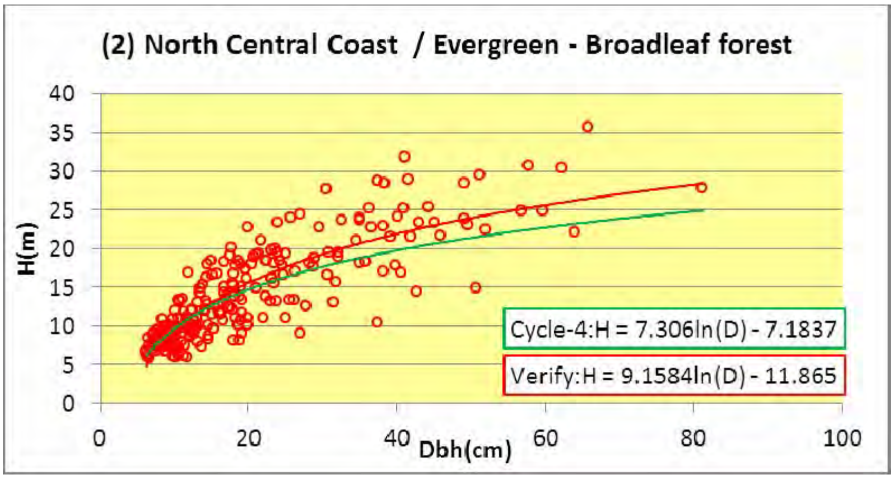


Figure 3.4.21 North Central Coast / evergreen broadleaf forest tree height curve

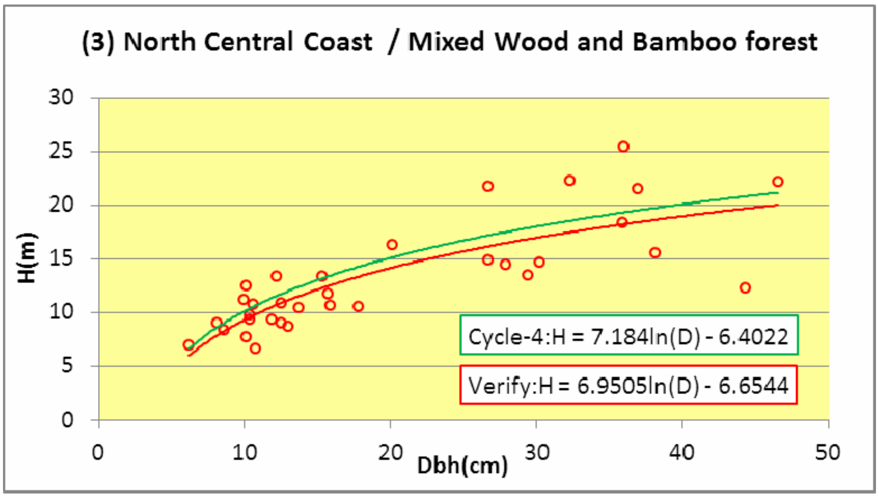


Figure 3.4.22 North Central Coast / mixed wood and bamboo forest tree height curve

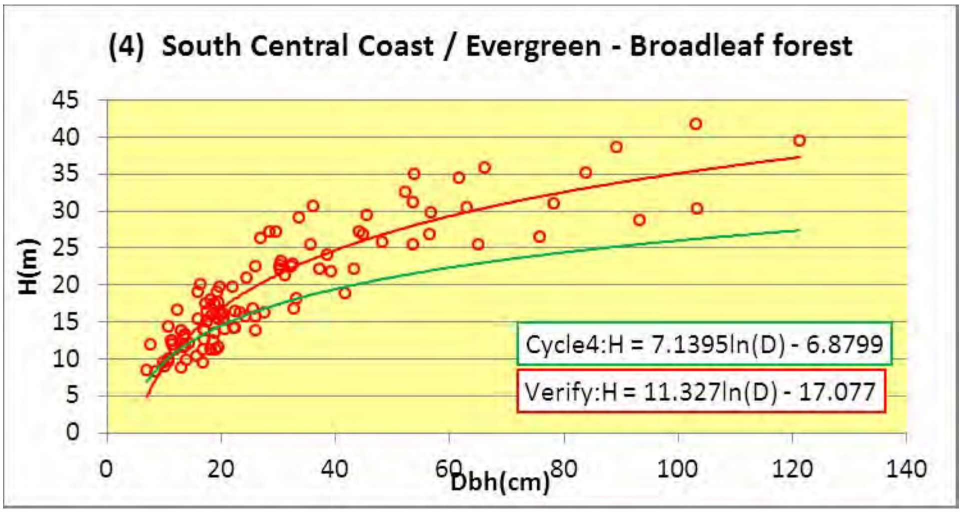


Figure 3.4.23 South Central Coast / evergreen broadleaf forest tree height curve

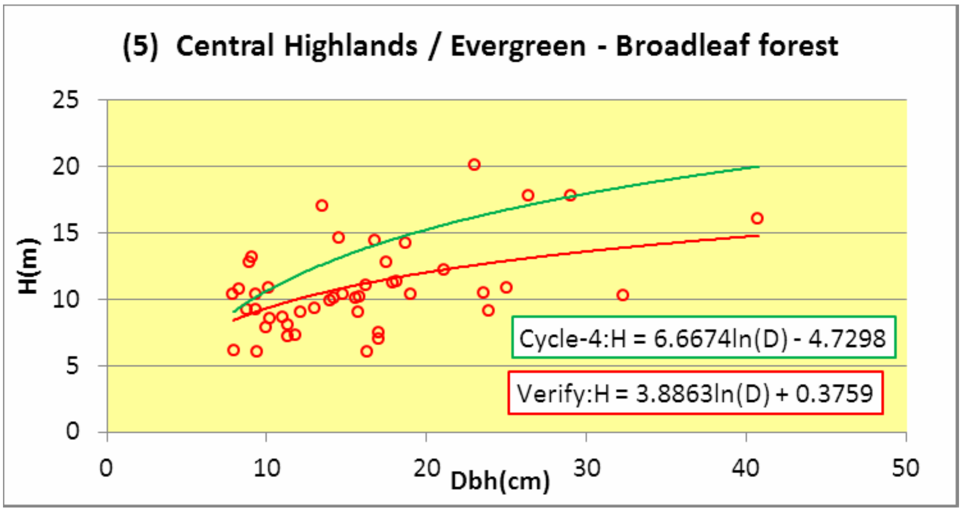


Figure 3.4.24 Central Highlands / evergreen broadleaf forest tree height curve

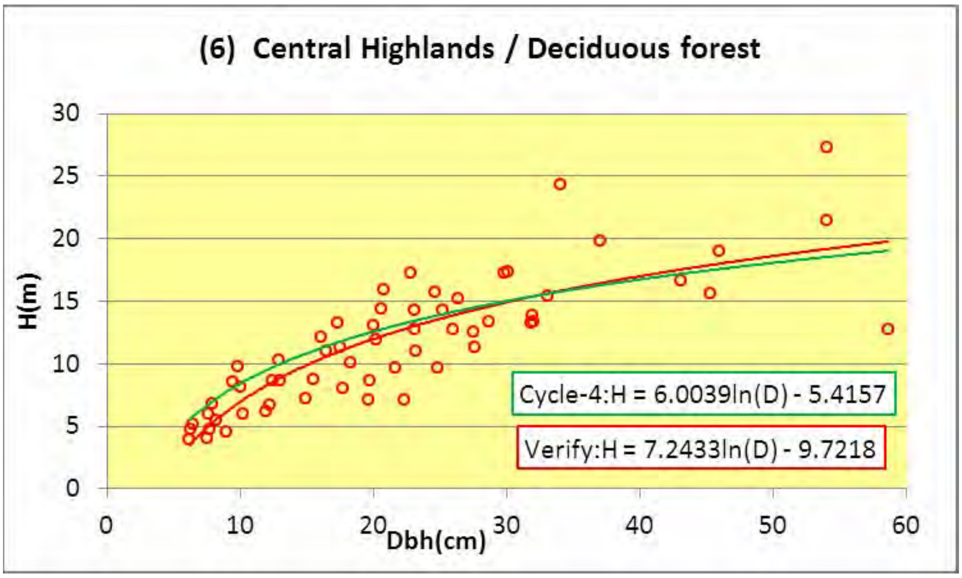


Figure 3.4.25 Central Highlands / deciduous forest tree height curve

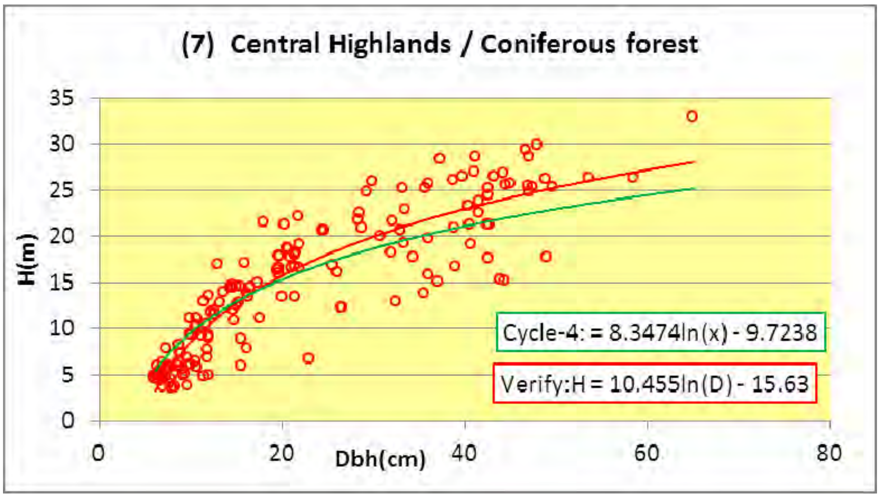


Figure 3.4.26 Central Highlands / coniferous forest tree height curve

With the exception of the Central Highlands / evergreen broadleaf tree height curve, which has a low correlation factor in the verification survey, the Cycle-4 tree height curve tends to be lower than that of the verification survey. Since the tree height curve for Cycle-4 is created from all trees whose heights are measures, by region and by forest type, it is the average tree height curve of at least several thousand trees, as shown in Figure3.4.27. For this reason, it is thought that the error in the tree height estimates by stand could be large.

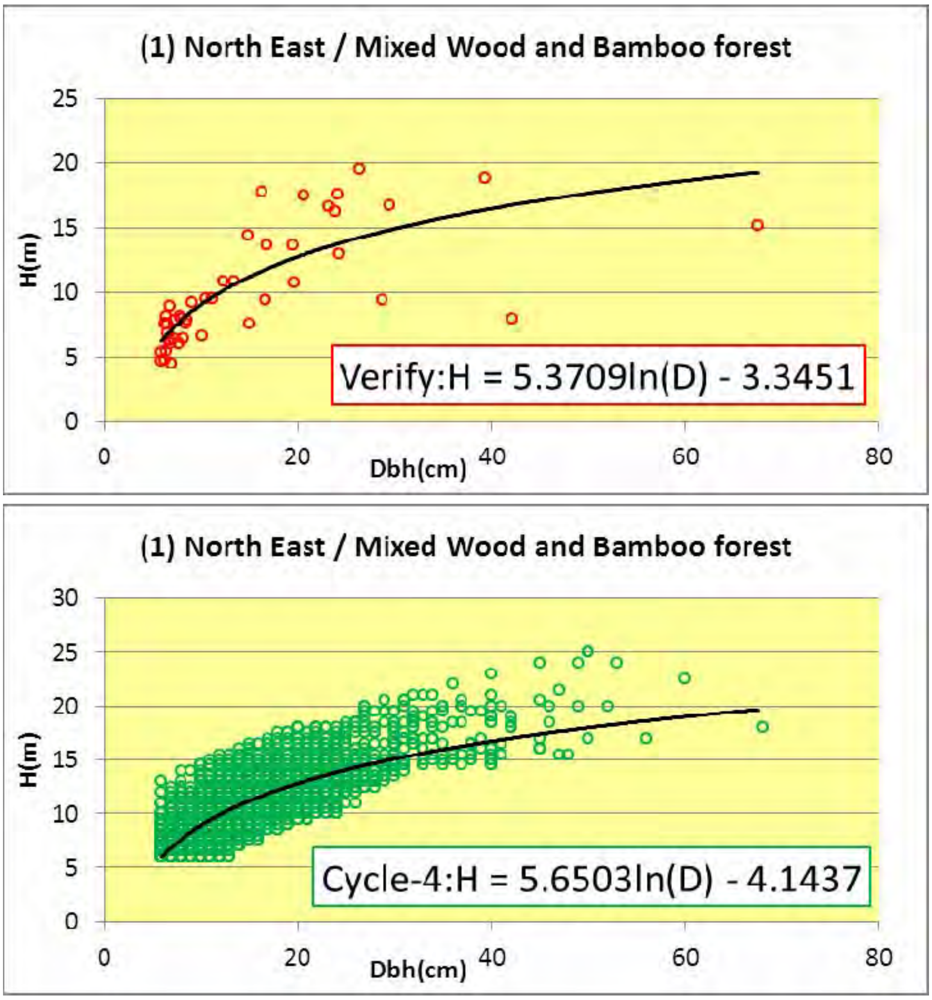


Figure 3.4.27 Tree height curves in the verification survey and Cycle-4

5) Timber Volume

The comparison by forest type and region is shown in Figure3.4.28. The basic statistics by forest type are shown in Table 3.4.15, Table 3.4.16. Here, "timber volume error" = "Cycle-4 timber volume" – "verification survey timber volume (8 cm or larger)", and "timber volume error rate" = "absolute value of timber volume error" / "verification survey timber volume (8 cm or larger)".

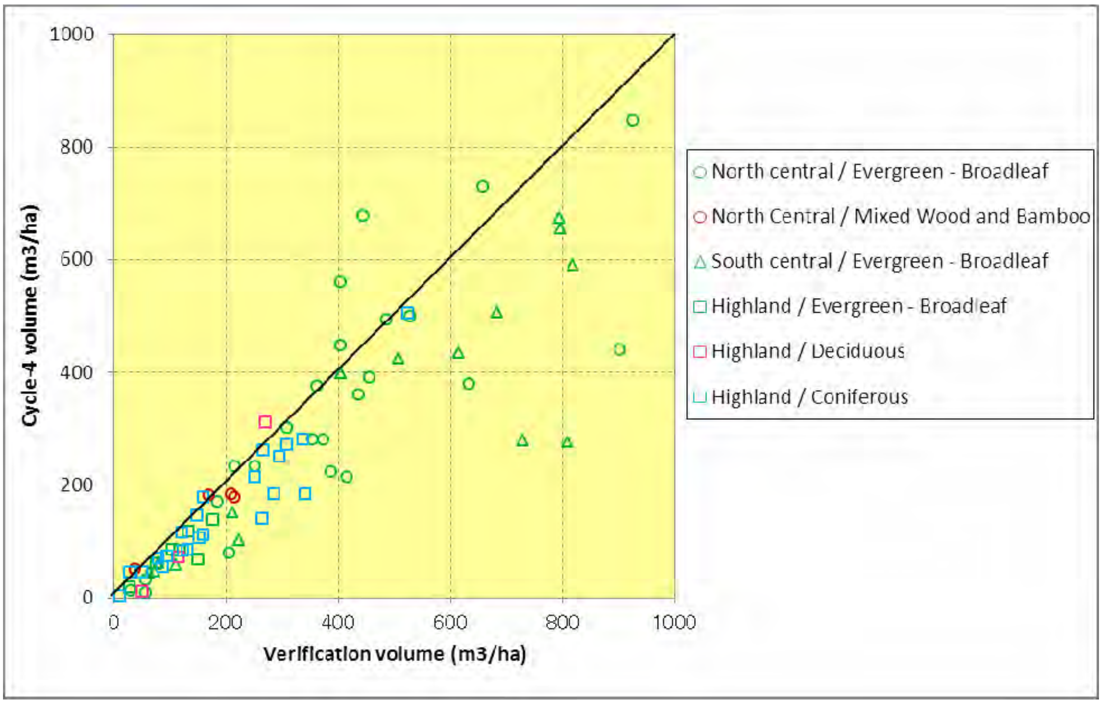


Figure 3.4.28 Comparison of timber volume by forest type

Table 3.4.15 Timber Volume Error Statistics

Region	Forest Type	Average (m^3/ha)	Standard Deviation (m^3/ha)	Maximum (m^3/ha)	Minimum (m^3/ha)	Data Points
North Central Coast	Evergreen - Broadleaf forest	-50.3	132.6	234.8	-462.5	24
	Mixed Wood and Bamboo forest	-9.1	22.7	13.7	-37.7	4
North Central Coast total		-44.4	123.9	234.8	-462.5	28
South Central Coast	Evergreen - Broadleaf forest	-147.7	150.1	-5.6	-532.8	15
South Central Coast total		-147.7	150.1	-5.6	-532.8	15
Central Highlands	Coniferous forest	-37.7	41.9	17.8	-156.3	22
	Deciduous forest	-14.7	39.6	41.3	-43.5	3
	Evergreen - Broadleaf forest	-31.5	23.3	-10.5	-83.3	7
Central Highlands total		-34.2	39.0	41.3	-156.3	32
Grand total		-60.7	113.1	234.8	-532.8	75

Table 3.4.16 Timber Volume Error Rate Statistics

Region	Forest Type	Average (%)	Standard Deviation (%)	Maximum (%)	Minimum (%)	Data Points
North Central Coast	Evergreen - Broadleaf forest	27.70	22.78	83.50	1.30	24
	Mixed Wood and Bamboo forest	18.38	11.05	36.50	7.50	4
North Central Coast total		26.37	21.74	83.50	1.30	28
South Central Coast	Evergreen - Broadleaf forest	32.17	17.58	65.90	1.40	15
South Central Coast total		32.17	17.58	65.90	1.40	15
Central Highlands	Coniferous forest	25.80	19.30	82.30	1.30	22
	Deciduous forest	44.60	27.18	80.80	15.30	3
	Evergreen - Broadleaf forest	28.16	13.25	55.10	12.30	7
Central Highlands total		28.08	19.82	82.30	1.30	32
Grand total		28.26	20.26	83.50	1.30	75

There is a tendency for the timber volume measured in Cycle-4 to be lower than that of the verification survey, with the error rate averaging at 28%. It tends to be that the larger the timber volume the greater the error.

Contributing factors could be that the area of the sub-plots tends to be too small, Cycle-4 is thought to have had a tendency to miss small-diameter trees, and the tree height curve is an underestimate.

Figure3.4.29 shows the distribution of the number of trees by diameter class for the sub-plots of 439.2 m^3/ha in Cycle-4 and 901.6 m^3/ha in the verification survey. In contrast to the verification survey's reverse "J" shape generally seen in natural forests, there is a strong possibility that Cycle-4 has missed small-diameter trees with a diameter at breast height of 6 to 10 cm. In addition, these sub-plots also miss some of the large-diameter trees of 60 cm or more, which have a high timber volume per individual tree.

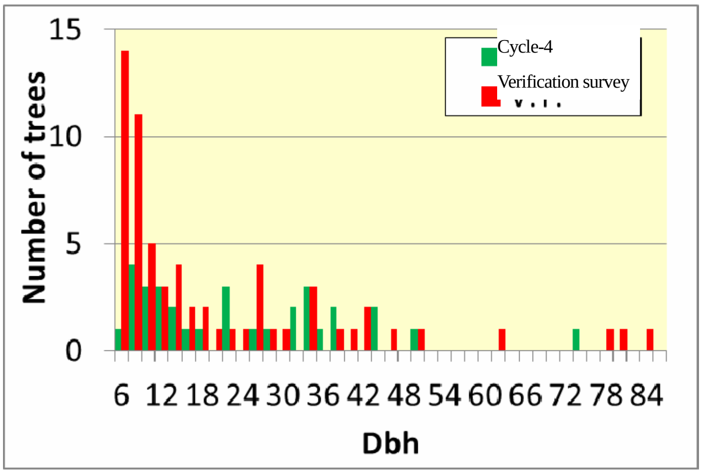


Figure 3.4.29 Chart: Distribution of number of trees by diameter class

In the case of trees in South Central Coast / evergreen broadleaf forest with a diameter of 121 cm at breast height in sub-plots of 275.9 m^3/ha in Cycle-4 and 808.8 m^3/ha for the verification survey, the tree height is 27.4 m by the Cycle-4 tree height curve, whereas the measured tree height is 39.5 m in the verification survey. The timber volume of individual trees is 14.2 m^3 and 20.3 m^3, respectively, which shows a discrepancy.

As the foregoing shows, the Cycle-4 timber volume estimates clearly tend to be on the low side. In the future it is necessary to improve the accuracy and repeatability, but the fact that such a tendency has come to light could be called an important step for Vietnam's REDD+.

3.4.4 Recommendation for the Next Period NFI

(1)Main Thrust of the Recommendation

From the perspective of a verification by a third-party organization, the result was that the repeatability of the sub-plots is low and the NFI survey methods need improvement. If these improvements are made, the precision and verifiability of the survey is likely to improve.

Below we offer recommendations in four areas: survey methods, timber volume estimation methods, sampling design, and verification system.

(2)Recommendation on Survey Methods

Regarding survey methods, the Study Team recommends placing a mark on trees that are subject to survey, using the latest surveying instruments, and performing training on usage methods.

Since there were no marks on the trees subject to the survey and there was no way to discern individual trees as survey trees, it was impossible to verify the measurement accuracy of the diameter at breast height or the tree height on an individual tree basis as well as accurately verify the number of trees subject to the survey. Placing a mark on the trees would lead to a recovery in repeatability. If possible, it would be desirable to mark trees for diameter measurement at their breast height positions with paint or spray paint, and to attach metal number tags to trees to mark them for tree height measurement(Figure3.4.30).

Figure 3.4.30 Spray paint (example in Japan) and aluminum number tag

For markings on trees, although there were some cases of the breast height position was filed and marked with paint, the wound would expand and prevent accurate diameter measurements from being taken. So this method is not suitable for continued surveys. Methods that wound the tree should be avoided.

As for surveying instruments, it would be desirable to use Vertex or other digital instruments for measuring horizontal distances for sub-plot setting and for measuring tree height. In addition, accurate measurements cannot be taken if the instructions for digital instruments are not followed, even if such instruments are used. Therefore training for surveyors is effective.

Training is also effective for creating a shared awareness among the surveyors about the significance of surveying and the content of the manual. The following represents content that is deemed necessary in training.

- The setting of sub-plot is by horizontal distance, not slope distance
- Methods of using digital instruments in measuring horizontal distance and tree height
- In some cases the broadleaf large-diameter trees in bamboo forests and the natural trees in plantation were not measured. The surveyors should be aware of the fact that the measurements are not of usable timber volume for the forest industry, but of biomass.

(3)Timber Volume Estimation Methods

Issues in timber volume estimation methods include the fact that the area is set too small in the sub-plot setting and that the tree height curve is created to apply to a broad range of trees.

As explained in the previous section, in setting the sub-plots it is necessary to use digital instruments to measure horizontal distances accurately.

The tree height curve was created for trees that number up in the several thousand currently by agro-Eco zone and forest type. In order to increase the precision of tree height estimation, more detailed stratification is necessary..

(4)Sampling Design

Considering how to improve starting from the methods of setting plots and sub-plots, the Study Team recommend making stake B metal, setting four-directional sub-plots, and stratified sampling and other redesign of sampling.

At present, there are few remaining stake B's, which identify the position of the subplots, which means verification survey cannot repeat the locations. Therefore, it is necessary use a material for a stake (metal, etc.) that can survive intentional burning. The identification of the position of stake B via GPS requires a GPS accurate to the single meter because the sub-plots are 20 m by 25 m, and currently such instruments are expensive and it seems it would be infeasible to provide them to everyone.

At the same time, most of the stake A's were preserved, and local residents were very aware of them. It is necessary to make the location of the plots identifiable from the one point of stake A. For example, the Study Team currently have 20 sub-plots north of A and 20 more east of A, but if the Study Team instead simply made the sub-plots extend 10 north, south, east, and west, that alone seems that it would lead to an increase in the accuracy of the sub-plots (Figure 3.4.31).

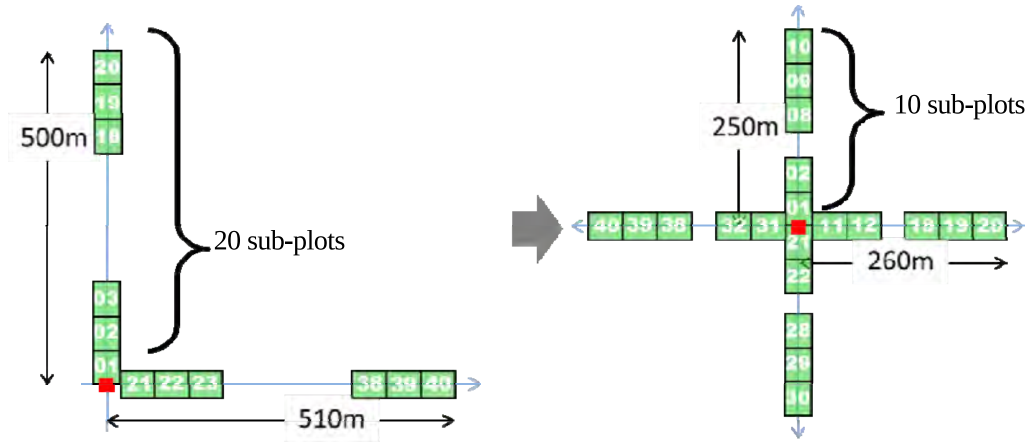


Figure 3.4.31 Recommendation for four-directional sub-plots

To make the plot setting even more reliable, it would be desirable to have something like circular plots that could be set from stake A only. Current sub-plots are set with a large area of 2 ha and a long transect of 500 m, which is a method suitable for natural forests fostering a diverse array of tree species over a broad scope or regions that have a flat topography. Vietnam also has many secondary forests where changes in land use happen quickly, as well as many plantation, and the topography is full of changes, which makes setting accurate transects a difficult task.

However, it is difficult to encompass 40 sub-plots that have a total area of 2 ha exactly by one plot. On the other hand, shrinking the plot area would require increasing the number of plots, which could present difficulties from a perspective of achievement. For this reason, stratification needs to be conducted for natural forest regions and plantation regions, and sampling numbers and plot areas need to be reconsidered (Figure3.4.32).

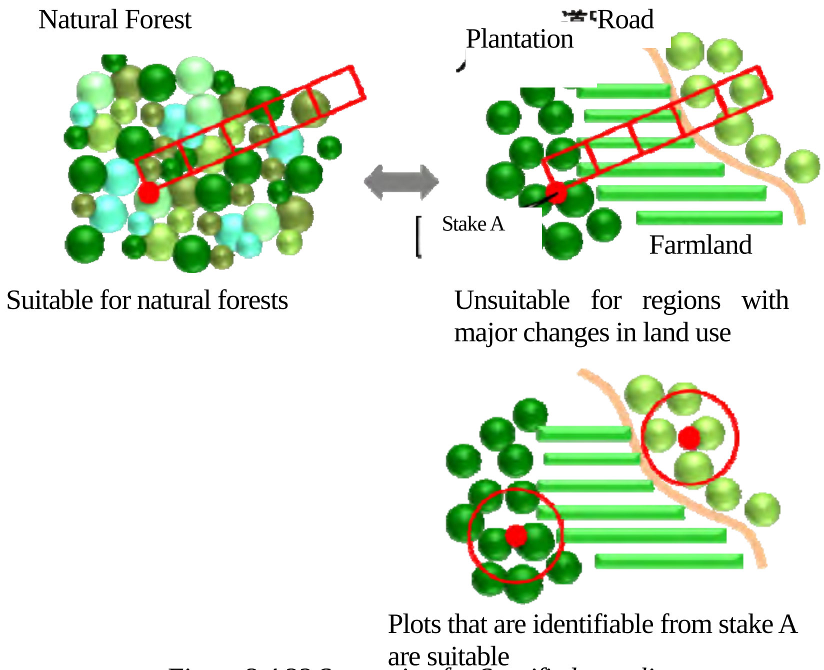


Figure 3.4.32 Suggestion for Stratified sampling

(5)Verification System

Due to the large amount of growth of fast-growing tree species and severe changes to land use, such as slashing and burning, the verification survey needs to be conducted in the same year as the NFI survey.

As a result of this past survey, it was concluded that verification of timber volume and QA/QC are inseparable. Verification of timber volume only at one point in time will be of no value to the country being surveyed if the accuracy is inadequate, and it makes verification more difficult to accommodate. Therefore, it is important that verification be performed under QA/QC that confirms the error factors, provides recommendations that go as far as improving them, and aims to ensure accuracy in the next verification.

In the re-measurement implemented after the NFI survey, the error factor was that the estimates from the results of the measurements had to be relied upon. Having a third party present at the same plots at the same time as the NFI survey and the verification survey would enable confirmation of the error factors of survey method misperceptions and so on.

Verification where the NFI surveyors re-measure each other's surveyed plots as a way of cross-checking them could also be considered. By re-measuring plots of different Sub-FIPI administration areas, any misperceptions or biases in the survey method by region could potentially be rectified.

(6)Conclusion

As explained above, it has come to light that the timber volume may have been underestimated in the Vietnam NFI. The sub-plots and individual trees are inherently lacking in repeatability, so there are many elements of the verification that are themselves difficult. However, the fact that this verification was conducted is the NFI's first step on QA/QC, and accuracy is expected to increase in the future.

An improvement in the accuracy of the NFI would means an improvement in the accuracy of carbon stock used in REDD+. As shown in Figure3.4.33, the verification's status as part of the PDCA cycle leads to increased effectiveness for REDD+.

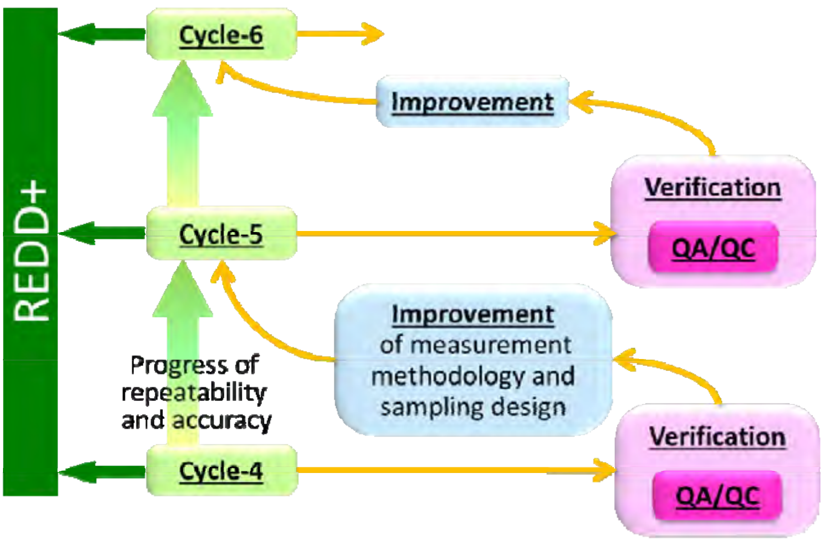


Figure 3.4.33 Model of Verification and REDD+