Estimating and monitoring forest carbon stock using fixed sample plots

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Background

- To establish national forest monitoring systems, use a combination of remote sensing and ground-based forest carbon inventory approaches for estimating forest carbon stocks and forest area changes.

Forest area | Average carbon stock

$$\text{Total carbon stock} = \Sigma\,(\text{Forest area}_i \times \text{Averaged carbon stock}_i)$$

- "Carbon stocks per unit area" can be estimated by measuring fixed sample plots, or stand carbon stock estimation models can be used (please see Chapter 9 in REDD-plus Cookbook) .

- Fixed sampling plots method is widely applied

Objective

To determine biomass and estimate carbon stock by different **forest type** and **logging history** using fixed sampling plots in Peninsular Malaysia

Hill forest (> 300m asl)

Lowland forest (< 300m asl)

Study area

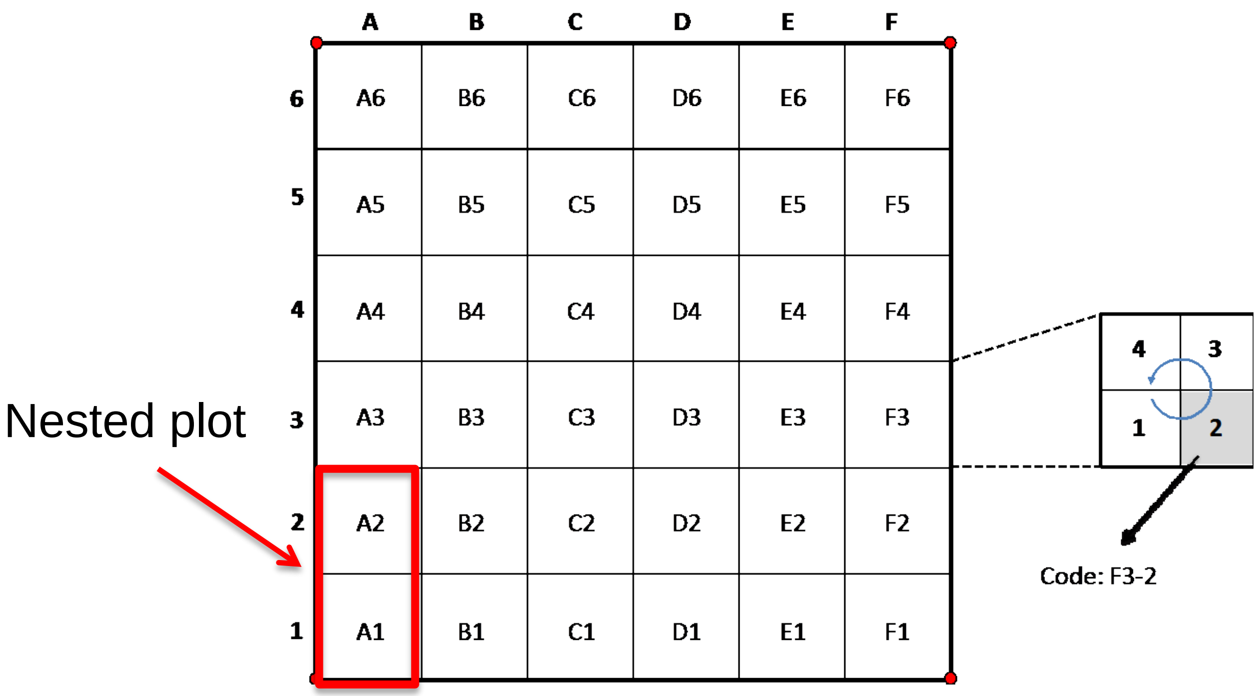
- Six states (Johor; Negeri Sembilan; Selangor; Pahan; Trengganu; Klentan) in Peninsular Malaysia
- Lowland and hill dipterocarp forests are our target forest types
- Both forest types also classify into “unlogged” and “logged” categories based on logging histories
- We set up 91 plots (0.36-ha in each plot) within above-mentioned 6 states

Fixed sampling plots allocation

Forest type	State						Total
	Johor	Kelantan	Negeri Sembilan	Pahang	Selangor	Terengganu	
Lowland unlogged			2	9	5	2	18
Lowland logged ≥ 10 years			7	15	6	3	31
Lowland logged < 10 years			6	2	2	7	17
Hill unlogged	3	2			5		10
Hill logged ≥ 10 years	2		1		3		6
Hill logged < 10 years		7			2		9
Total	5	9	16	26	23	12	91

Design of fixed sampling plot

Numbering of sub-plots for tree locations



- All living trees larger than 10 cm in DBH are measured within a 0.36-ha plot (60 m x 60 m)
- Small trees ranged between 5 cm and 10 cm in DBH are measured within a nested sub-plot (10 m x 20 m)

Methods of carbon stock estimation

Aboveground biomass (AGB): Kato et al. (1978)

$W_{Stem} = 0.313\ (DBH^2H)^{0.9733}$

$W_{Branch} = 0.0390\ (DBH^2H)^{1.041}$

$1/W_{Leaf} = 1/(0.124\ W_S^{0.794}) + 1/125$

$1/H = 1 / 2.0\ DBH + 1/61$

$AGB = W_{Stem} + W_{Branch} + W_{Leaf}$

Belowground biomass (BGB): Niiyama et al. (2010)

$W_{Root} = 0.023\ DBH^{2.59}$

$BGB = W_{Root}$

After calculating tree biomass, carbon stock of a tree will be obtained by multiplication of 0.47 (IPCC)

Approach to raise the estimating precision
~Important key of successful monitoring~

Set up distinct stake within each sampling plot

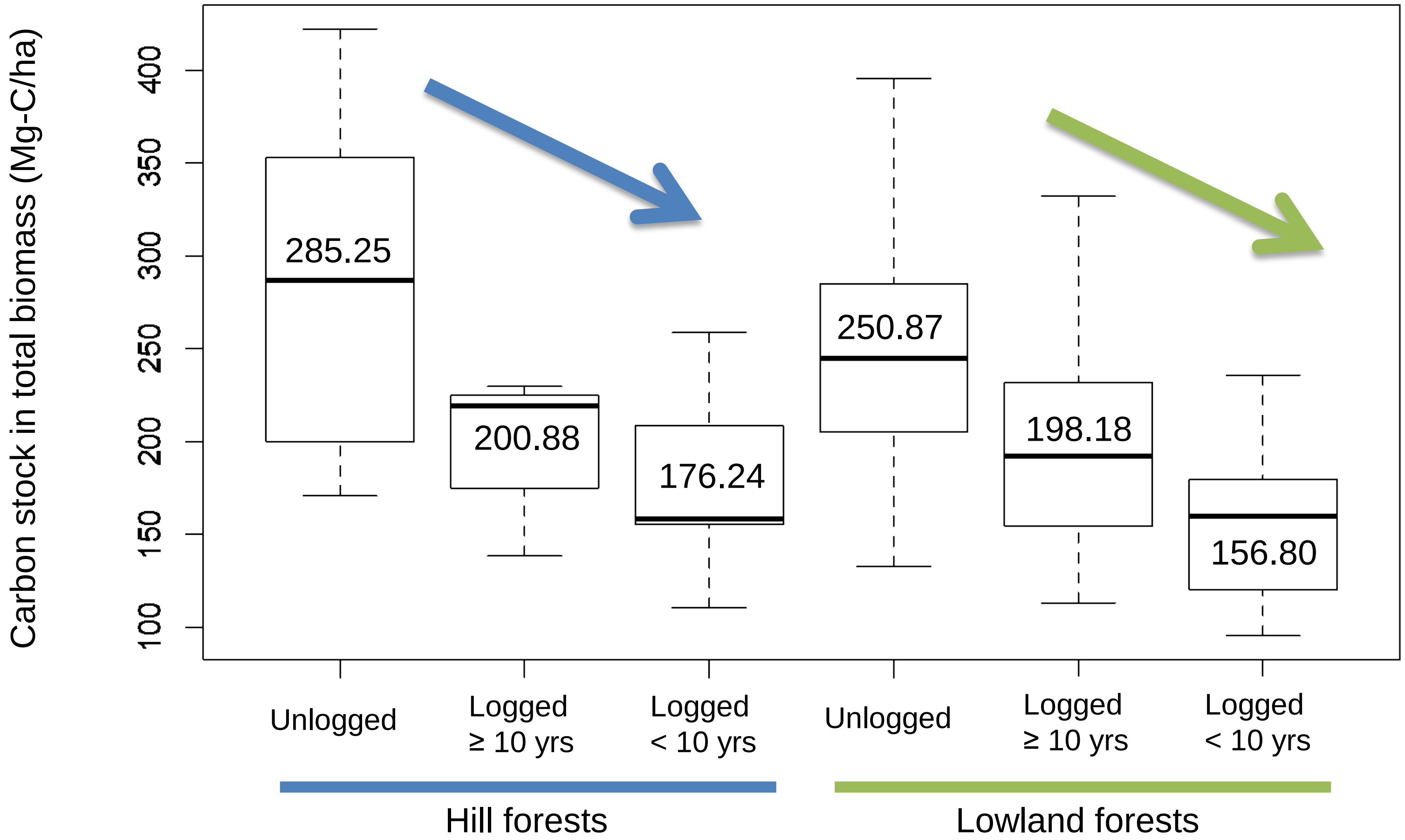
Mark measuring position

Make clear rules for DBH measuring

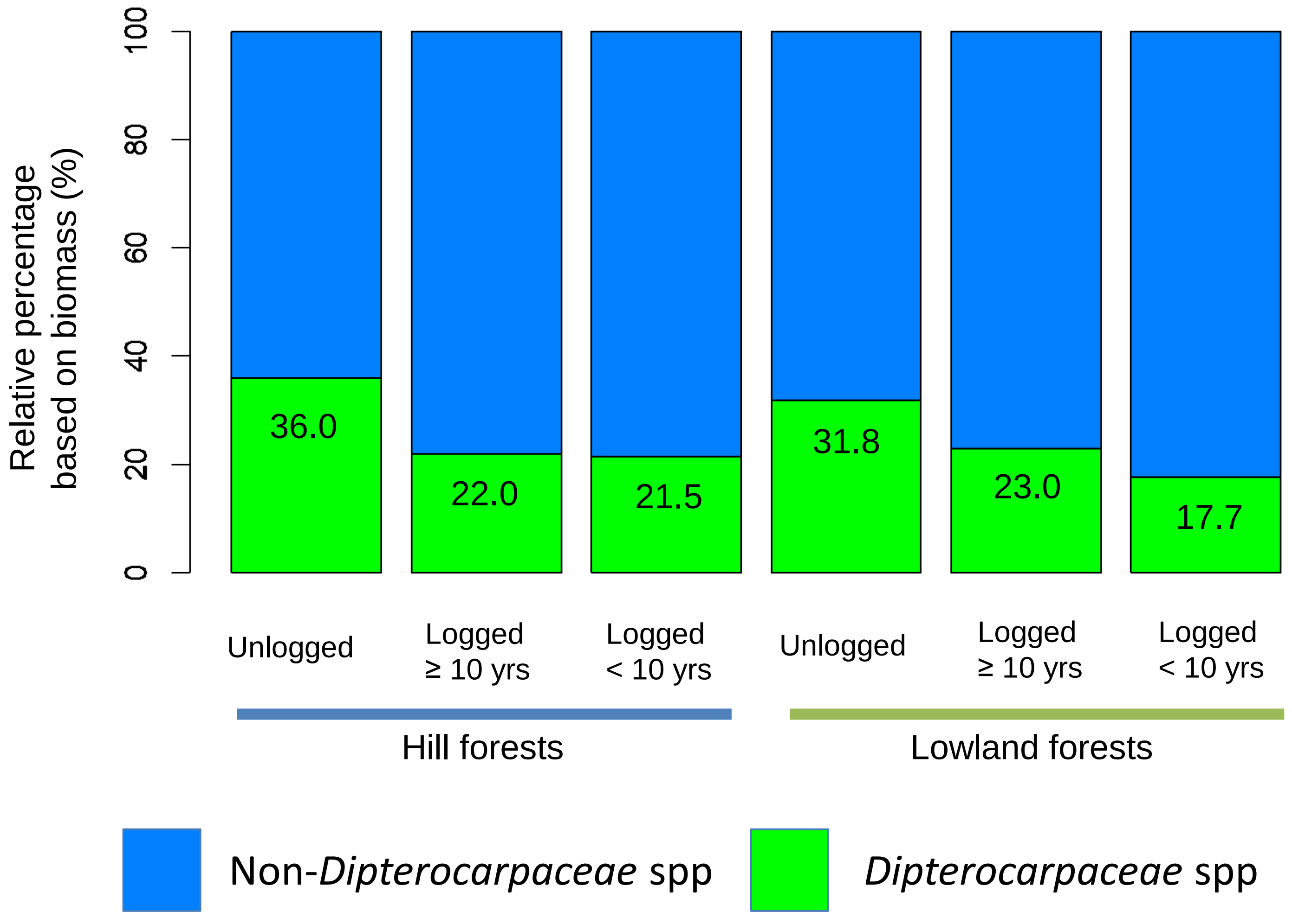
- Efficient planning is essential to reduce unnecessary works, costs and ensure reliable carbon estimates and carbon stock changes.

Results

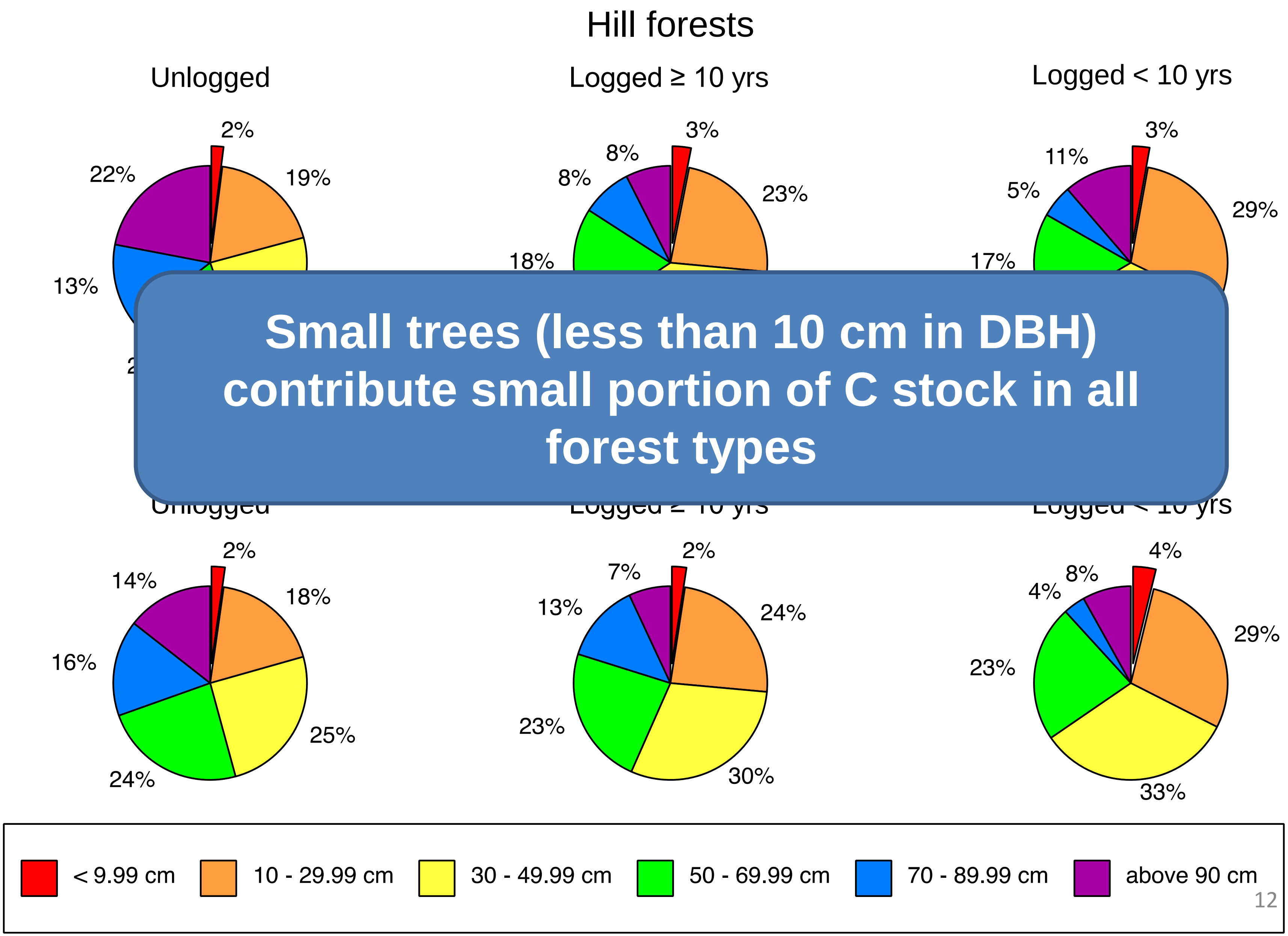
Comparison of C stock



Comparison of species composition ~Percentage of *Dipterocarpaceae* spp ~



Percentage of C stock based on DBH class



Small trees (less than 10 cm in DBH) contribute small portion of C stock in all forest types

Large trees explain C s

Carbon stock in total biomass (Mg-C/ha)

Hill forests

5 30 35

Density of large trees (DBH ≥ 70 cm) /ha

Because large trees dominate forest C stock, accurate & precise measurement of DBH is important in carbon monitoring system.

Small trees contribute species diversity

Species number based on the maximum DBH class

Maximum DBH class	Species #	Relative %
Less than 10cm	111	22.9
10 - 29.9 cm	193	39.8
30 - 49.9 cm	116	23.9
50 - 69.9 cm	35	7.2
70 – 89.9 cm	15	3.1
Larger than 90 cm	15	3.1

About one fourth species do not reach 10 cm in DBH in hill forest at Semangkok FR.

Key messages

- Carbon stock estimation using fixed sampling plots is practical way unless it cost high.
- Monitoring of fixed sampling plots would provide us important information to carbon stock changes
- Although small size trees (i.e. less than 10 cm in DBH) account small portion of C stock, their species composition contribute to high plant species diversity

Thank you for your attention

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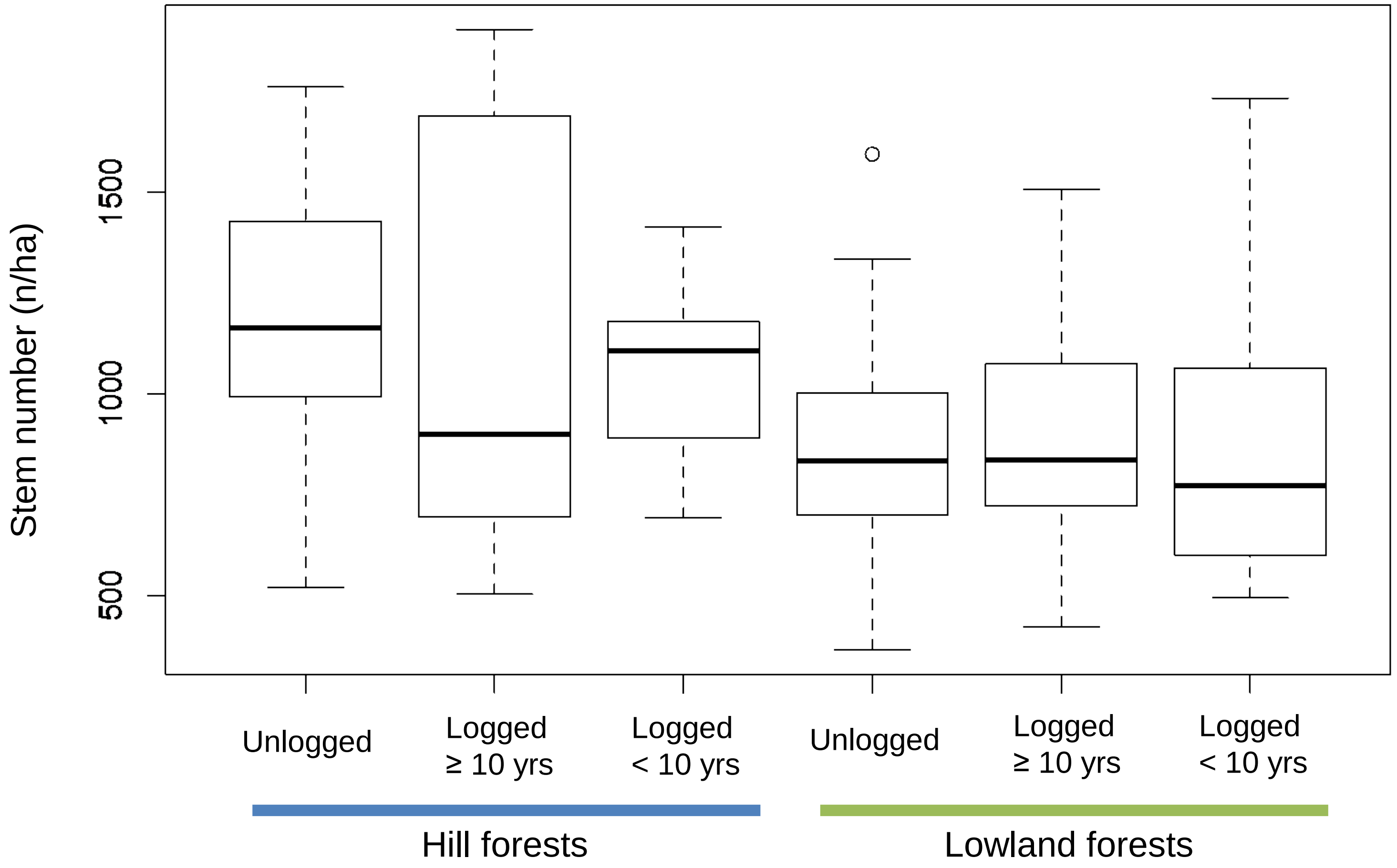
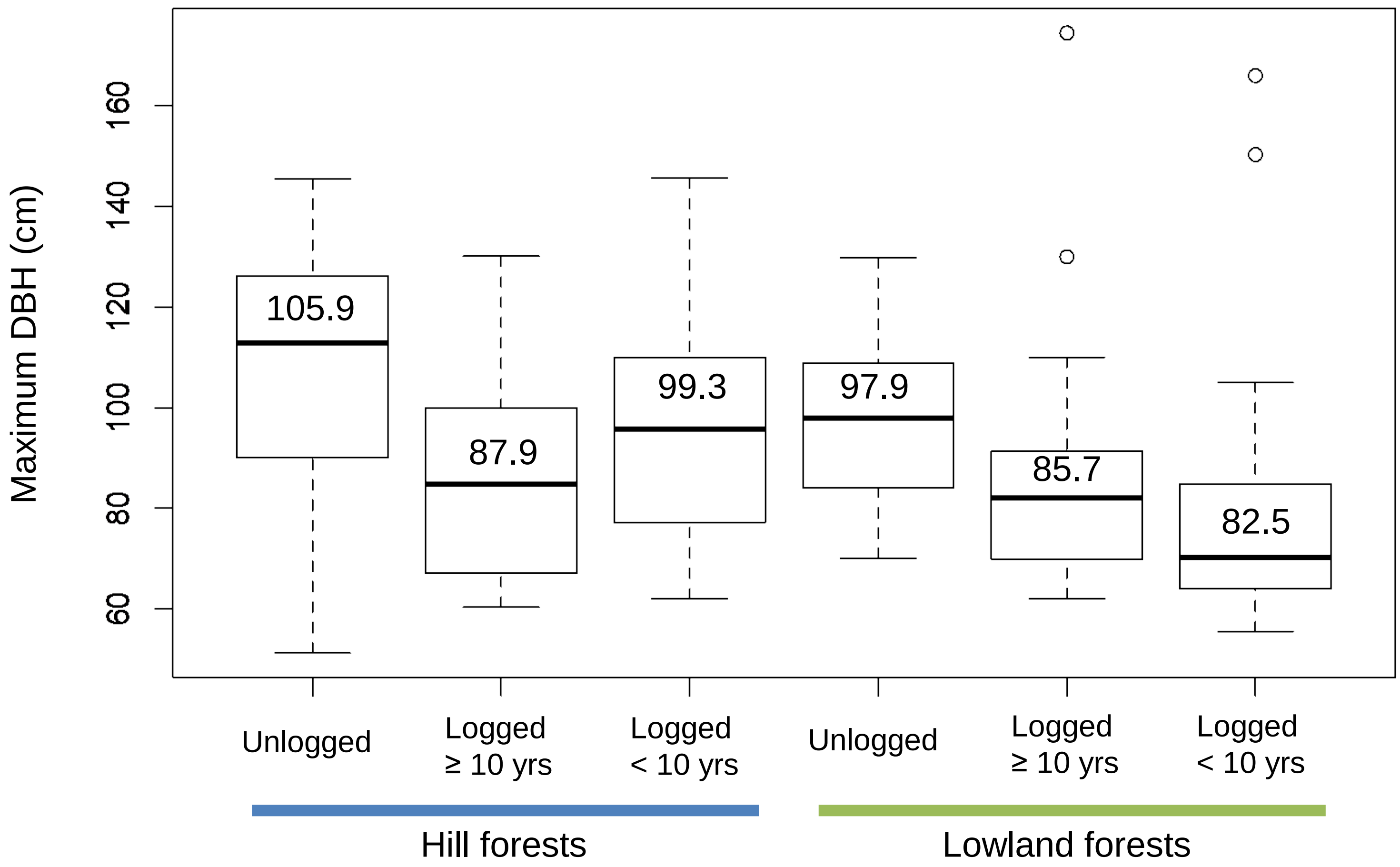
Lowland Dipterocarp Forest, Malaysia

Comparison of stem number



Comparison of maximum DBH



Examples of fixed sampling plot implementations

Papua New Guinea (Fox et al. 2010)

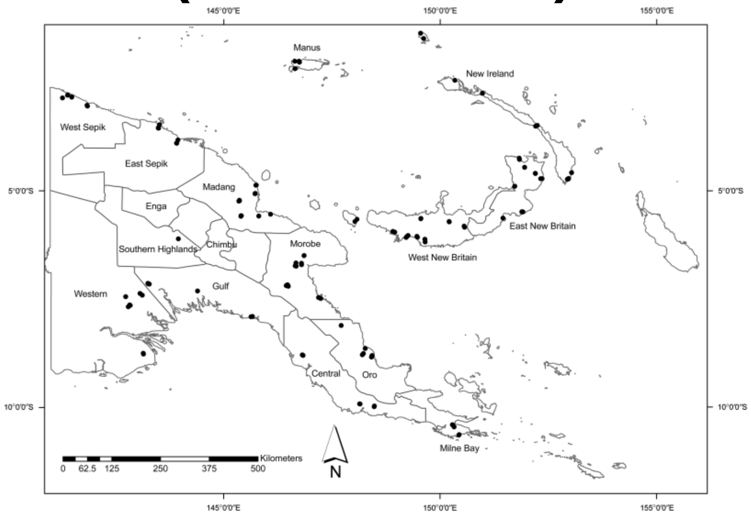


TABLE 3. *Estimates of the mean carbon stock in different pools in different forest types in Papua New Guinea. Quantities for all components are Mg C/ha (± SD).*

Forest C component	Secondary Lowland	Secondary Lower-montane	Secondary Mid-montane	Primary Lowland	Primary Lower-montane
AGLB $_{> 10 cm}$	66.3 (18.8)	58.8 (9.8)	61.3 (19.6)	106.3 (22.7)	141.1 (25.6)
AGLB $_{< 10 cm}$	6.7	5.8	6.1	5.1	7.1
Total AGLB	73.0	64.6	67.4	111.4	148.2
FL	0.7	1.5	1.5	2.6	5.6
CWD	16.6	14.7	15.3	10.3	14.1
Total NLB	17.3	16.2	16.8	12.9	19.7
Total AGB	90.2 (25.6)	80.9 (13.5)	84.3 (26.9)	120.8 (22.5)	167.9 (30.4)
Sample size	115	3	2	10	2

Cambodia (Samreth et al. 2012)

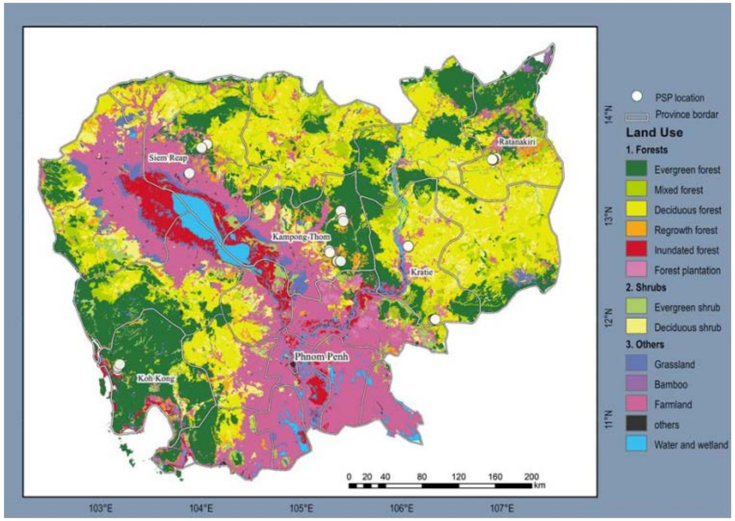
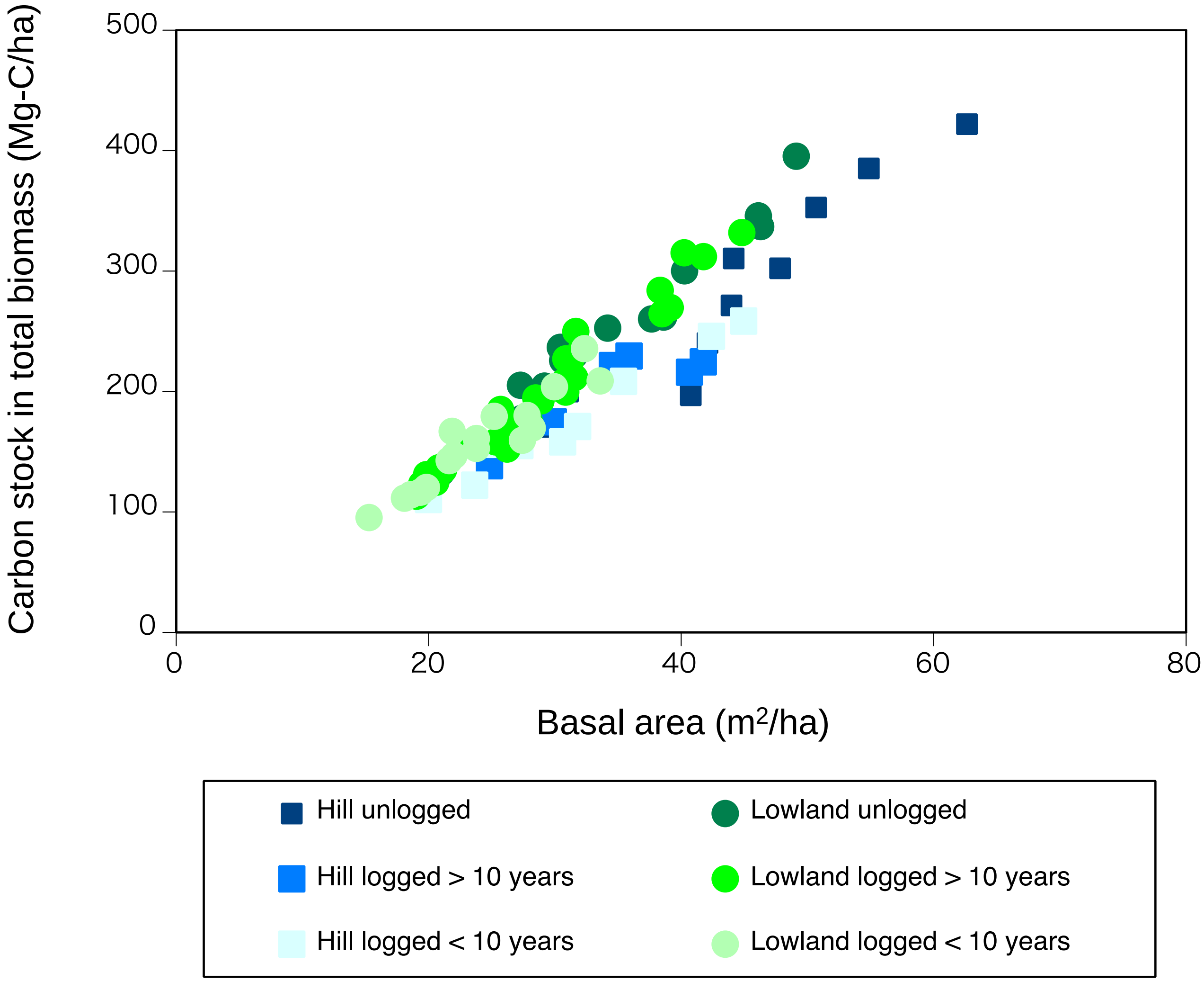


Table 2. Tree carbon stocks in each forest type on a nationwide scale

Forest type	Forest area in 2006 (ha)	Averaged carbon stock in 2000-2001 ($Mg\text{-}Cha^{-1}$)	Total carbon stock (Tg-C)	
Evergreen forest*	5,031,540	163.8 ± 7.8	824.2±39.2	N = 59
Deciduous forest	4,692,098	56.2 ± 6.7	263.9±31.3	N = 20
Total	9,723,638		1,088.1±50.2	

* Including Semi-evergreen forest.
Carbon stocks are shown in mean ± standard error.


Carbon stock in total biomass (Mg-C/ha)
500
400
300
200
100
0
0
20
40
60
80
Basal area (m2/ha)
Hill unlogged
Lowland unlogged
Hill logged > 10 years
Lowland logged > 10 years
Hill logged < 10 years
Lowland logged < 10 years