THE SIXTH NATIONAL FOREST INVENTORY

Ahmad Fadzil Abdul Majid[1], Roslan Rani[1], Aldrich Richard[1], Rosaizan Haryani Rosli[1], Jamal Shuhaily Shahar[1], Mohd Faris Sobri[1], Azuan Mohd Sukri[1], Jennifer Anak Francis[1], Rabi'atul Adawiyah Jamil[1], Muhammad Ameer Shohaimay[1], Nurul Aidah Bahrum[1]

[1]*Forestry Department Peninsular Malaysia, Jalan Sultan Salahuddin, 50660 Kuala Lumpur.*

**Author for correspondence. Email:* rabiatul@forestry.gov.my

ABSTRACT

National Forest Inventory (NFI) is an initiative implemented by the Forestry Department of Peninsular Malaysia (FDPM) to gather qualitative and quantitative information on forest resources to aid in the planning and management of the nation's forest resources. The NFI began as early as 1970 with the First NFI (NFI-1) and has been conducted every ten years. The latest NFI, the Sixth NFI (NFI-6), started in 2020 and continued until 2023. The implementation of NFI-6 in Peninsular Malaysia covers natural inland forests and peat swamp forests with an area of approximately 5,578,903 hectares (ha) and has been classified into 18 forest strata based on forest type, logging status, and the elevation above sea level of the forest area. A total of 790 Sampling Units (SU) were surveyed, and the selection of SU was done randomly using a stratified random sampling concept. Based on the overall analysis of the NFI-6 survey data, the results for the number of trees per hectare (trees/ha), basal area per hectare (m^2/ha), and tree volume per hectare (m^3/ha) for trees sized 10 centimetres (cm) and above are 333.39 trees/ha, 16.82 m^2/ha, and 170.22 m^3/ha, respectively. In addition to the woody plants surveyed, other plants such as medicinal plants, rattan, bamboo, palms, and carbon stock were also surveyed during NFI-6. From the analysis of the NFI-6 data, the estimated carbon stock for forests in Peninsular Malaysia is 112.32 t C/ha.

Keywords: National Forest Inventory), Permanent Reserved Forest, Forest Inventory, Forest Biodiversity, Management

INTRODUCTION

Background on the National Forest Inventory (NFI)

Malaysia has rich natural forests with diverse plant and animal life, which are crucial for the country's economy and environment. As a tropical country with high biodiversity, keeping up-to-date information on forests is essential for proper planning and management to ensure the forests in Peninsular Malaysia are sustained.

To achieve this, the Forestry Department of Peninsular Malaysia (JPSM) has been gathering data on forests since 1970 through the National Forest Inventory (NFI). The NFI collects important information about the forests and is done every 10 years. The first NFI (NFI-1) began in 1970 with help from the United Nations. The second and third NFIs were done in 1981 and 1991, with similar collaboration. The fourth NFI (NFI-4) took place between 2002 and 2004, with technical support from a Malaysia-Germany project, and the fifth NFI (NFI-5) was carried out from 2010 to 2013 by JPSM alone.

Recently, JPSM completed the sixth NFI (NFI-6), which ran from 2020 to 2023. This latest NFI used methods from the fourth and fifth NFIs and covered inland forests and peat swamp forests in protected and government lands in Peninsular Malaysia.

NFI-6 serves as a platform for collecting quantitative and qualitative data on forest resources as follows:

a) Up-to-date information on forest resources at the national level (Peninsular Malaysia) for forest management planning purposes;
b) Information on trees (number, basal area, and volume), medicinal plants, rattan, bamboo, and palms;
c) Information on the volume of standing trees in the forest, categorized by forest strata, diameter, species, and species groups;
d) Estimates of carbon stock content based on tree inventory data;
e) Additional information related to forest resources and growth at the national level; and
f) Additional information for the sustainable forest management control mechanism at the national level.

METHODOLOGY

The regions been covered for NFIs in Peninsular Malaysia and included two types of forests which are natural inland forests and peat swamp forests. The field methods for NFI-6 are detailed in the NFI-6 guidebook and manual. NFI-6 uses a stratified random sampling design, updated from NFI-4 and NFI-5. The reasons for keeping this design are:

a) It was used in NFI-4 and NFI-5, providing consistent data;
b) It has been tested for effectiveness with input from the Malaysia-German Sustainable Forest Management Project;
c) Using the same design helps determine the number of Sampling Units (SU) by analyzing data from NFI-5;
d) 141 Continuous Forest Inventory (CFI) units from NFI-5 were included in NFI-6; and
e) Experience from NFI-5 reduces training costs for the team.

Each SU contains four (4) Point Samples, four (4) Circular Samples, and three (3) Strip Samples, covering an estimated area of 3.14 hectares (ha), along with an additional one (1) clip plot. The design of NFI-6 is as shown in **Diagram 1** and the description of the parameters inventoried in each SU and the census information of NFI-6 are as shown in **Tables 1 and 2**.

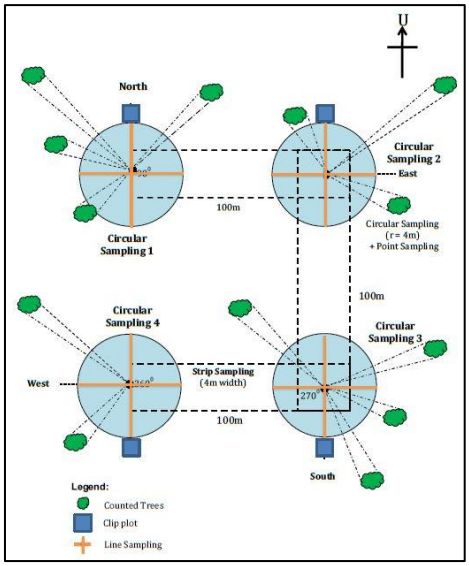


Diagram 1: Design of NFI-6 Sampling Unit (SU)

Table 1: Details of the Parameters Surveyed in the NFI

Design	Description
Point Sampling	• Four (4) points in each unit. • Uses Basal Area Factor 4 (BAF 4) for consistency with previous surveys. • Surveys trees with a diameter at breast height (dbh) of 10 centimetres (cm) or more within 50 metres (m) of the centre point.
Circular Sampling	• Four (4) circles with a 4 m radius in each unit. • Surveys seedlings and saplings (1.5 m tall to < 10.0 cm dbh) and medicinal plants. • Covers a total area of 0.02 ha.
Strip Sampling	• Three (3) rectangular strips, each 100 m long and 4 m wide. • Surveys non-timber resources like rattan, bamboo, and palms. • Covers a total area of 0.12 ha.
Dead Tree Line Sampling	• 25 m lines from the centre of each circle. • Records dead trees/logs with a diameter of less than 10 cm.
Relaskop Dead Tree Sampling	• Surveys dead trees with a dbh of 10 cm or more within 50 m of the centre point using a relaskop.
Clip Plot Sampling	• Collects and weighs forest litter from a 0.5 m x 0.5 m area. • Small samples (less than 100 grams) are taken for further analysis.

Table 2: Information on the NFI-6 Survey

Census Information	Description
Wood Resources	• The wood resources surveyed include seedlings (1.5 m tall to < 5.0 cm dbh), saplings (5 cm to < 10.0 cm dbh), and trees larger than 10 cm dbh. • These are surveyed in all Point and Circular Sampling.
Non-timber Resources	The non-timber resources surveyed include: • Six (6) rattan species: Manau, Manau Tikus, Dok, Dahan, Sega, and Semambu; • Six (6) bamboo species: Semantan, Beti, Beting, Betong, Semeliang, and Dinding; and • Eight (8) selected palm species: Bertam, Bayas, Nibung, Serdang, Ibol, Enau, Kelubi, and Salak. These are surveyed along the Strip Sampling.
Medicinal Plants	• Twelve (12) medicinal plant species are surveyed in NFI-6, including Tongkat Ali, Kacip Fatimah, Tongkat Haji Samad, Hempedu Beruang, Gajah Beranak, Keladi Murai, Alek Besi/Alek Tembaga, Ubi Jaga, Lemba, Sepit, Payung Ali, and Lekir. • These plants are surveyed in the Circular Sampling.
Carbon Stocks	○ Carbon content information is obtained and monitored through recorded data. ○ Four (4) types of carbon data are analysed: • Above and below ground carbon stock; • Carbon stock in dead wood; • Carbon stock in forest litter.

Determination of Sampling Unit (SU) Number

The number of SU in NFI-6 is based on the Coefficient of Variation (CV) and Allowable Error (AE) at the specified Probability Level (t). The formula used to determine the number of SU is as follows:

$$\mathbf{n} = \frac{\mathbf{t}^2 \times (\mathbf{CV}\%)^2}{(\mathbf{AE}\%)^2}$$

Whereas,

n : Number of Sampling Units (SU)
t : Value at the 90% probability level (t0.1 = 1.645)
AE% : Allowable Error
CV% : Coefficient of Variation

The value of **'t'** at the probability level and the Allowable Error (AE) are determined by consensus, ensuring that the estimates fall within an acceptable range. The Coefficient of Variation (CV) is obtained from Basal Area calculations using data from NFI-5. The specified probability level for **'t'** is 90% (t0.1 = 1.645). **Table 3** shows the values of CV and AE used in determining the number of SU. However, for NFI-6, the field surveys were conducted with a total of 790 SU, exceeding the required number of 659 SU specified in **Table 3**.

Table 3: Number of Sampling Units (SU) for Each Forest Stratum in NFI-6 Based on Coefficient of Variation (CV) and Acceptable Error (AE)

Strata Code	NFI-6 Forest Strata	CV %	AE %	Number of SU
1	Primary Lowland Forest: Lowland and Hill Forest	53	20	19
2	Primary Hill Forest: High Hill Forest	78	20	42
3	Logged Lowland & Hill Forest (1-10 years)	71	20	34
4	Logged High Hill Forest (1-10 years)	76	20	39
5	Logged Lowland & Hill Forest (11-20 years)	71	20	34
6	Logged High Hill Forest (11-20 years)	69	20	32
7	Logged Lowland & Hill Forest (21-30 years)	65	20	28
8	Logged High Hill Forest (21-30 years)	100	20	68
9	Logged Lowland & Hill Forest (>30 years)	53	20	19
10	Logged High Hill Forest (>30 years)	71	20	34
11	Primary Peat Swamp Forest	93	20	58
12	Logged Peat Swamp Forest (≤40 years)	94	20	60
13	Logged Peat Swamp Forest (>40 years)	110	20	82
14	Forest Outside Permanent Reserved Forests	70	20	33
15	Peat Swamp Forest Outside Permanent Reserved Forests	72	20	35
16	Protected Forest: Lowland & Hill Forest	37	20	9
17	Protected Forest: High Hill Forest	44	20	13
18	Protected Forest: Mountain Forest	53	20	19
TOTAL				**659**

Classification and Stratification of Forests

Determination of Forest Strata

The NFI-6 uses the same 18 forest strata as NFI-5, based on land status, forest type, elevation, and logging status, as detailed in **Table 4**. Forest strata for logged areas are determined using data up to 2020. These strata help define the area of each forest type, determine the number and distribution of SU, assess the actual forest conditions in the field, and create the Forest Resource Map.

Table 4: Description of Forest Strata for NFI-6

Strata Code	Description
1. Primary Lowland Forest: Lowland and Hill Forest	Primary forest in Permanent Reserved Forests (PRF) below 750 m elevation, not yet logged.
2. Primary Hill Forest: High Hill Forest	Primary forest in PRF between 750 m and 1,200 m elevation, not yet logged.
3. Logged Lowland & Hill Forest (1-10 years)	Primary forest in PRF below 750 m elevation, logged between 2011 and 2020.
4. Logged High Hill Forest (1-10 years)	Primary forest in PRF between 750 m and 1,000 m elevation, logged between 2011 and 2020.
5. Logged Lowland & Hill Forest (11-20 years)	Primary forest in PRF below 750 m elevation, logged between 2001 and 2010.
6. Logged High Hill Forest (11-20 years)	Primary forest in PRF between 750 m and 1,000 m elevation, logged between 2001 and 2010.
7. Logged Lowland & Hill Forest (21-30 years)	Primary forest in PRF below 750 m elevation, logged between 1991 and 2000.
8. Logged High Hill Forest (21-30 years)	Primary forest in PRF between 750 m and 1,000 m elevation, logged between 1991 and 2000.
9. Logged Lowland & Hill Forest (>30 years)	Primary forest in PRF below 750 m elevation, logged before 1990.
10. Logged High Hill Forest (>30 years)	Primary forest in PRF between 750 m and 1,000 m elevation, logged before 1990.
11. Primary Peat Swamp Forest	Primary peat swamp forest in PRF, located in wet or acidic areas.
12. Logged Peat Swamp Forest (≤40 years)	Peat swamp forest in PRF, logged between 1981 and 2020.
13. Logged Peat Swamp Forest (>40 years)	Peat swamp forest in PRF, logged before 1981.
14. Forest Outside Permanent Reserved Forests	Forested areas outside PRF, including government land, reserve land, and private land.
15. Peat Swamp Forest Outside Permanent Reserved Forests	Peat swamp forest outside PRF, including government land, reserve land, and private land.
16. Protected Forest: Lowland & Hill Forest	Forest in PRF classified under various protection categories by the National Forestry Act 1984, below 750 m elevation. Also includes protected areas like national parks and wildlife reserves outside PRF.
17. Protected Forest: High Hill Forest	Forest in PRF classified under various protection categories by the National Forestry Act 1984, between 750 m and 1,200 m elevation. Also includes protected areas like national parks and wildlife reserves outside PRF.
18. Protected Forest: Mountain Forest	Forest in PRF classified under various protection categories by the National Forestry Act 1984, above 1,200 m elevation. Also includes protected areas like national parks and wildlife reserves outside PRF.

Key Findings/Inventory Results

Number of Seedlings and Small Saplings

Counting the number of seedlings and small saplings is crucial for assessing forest density. In NFI-6, this includes seedlings with heights of 1.5 m and those with diameters less than 5.0 cm, as well as small saplings with diameters between 5.0 cm and less than 10.0 cm.

Table 5 shows the number of seedlings and small saplings per hectare for entire stratum, categorized into dipterocarp and non-dipterocarp groups across all surveyed strata in NFI-6. The survey recorded 1,684.55 seedlings per hectare and 310.44 small trees per hectare.

Table 5: Number of Seedlings and Small Saplings per Hectare (number/ha) for All Strata

Category	Dipterocarp (count/ha)	Non-Dipterocarp (count/ha)	Total (count/ha)
Seedlings (1.5 m tall to < 5.0 cm dbh)	102.39	1,582.16	1,684.55
Small Saplings (5 cm to < 10.0 cm dbh)	11.08	299.37	310.44

Meanwhile for the result for the number of seedlings and small saplings per hectare for each forest stratum (count/ha) is as shown in **Table 6**. Based on the **Table 6**, Stratum 1 (Virgin Inland Forest: Lowland Forest & Hill Forest) recorded the highest number of seedlings per hectare and small saplings per hectare, with 2,188.81 trees/ha and 418.66 trees/ha, respectively. Meanwhile, Stratum 18 (Protected Forest: Mountain Forest) recorded the lowest number of seedlings per hectare and small trees per hectare, with 402.96 trees/ha and 91.58 trees/ha, respectively.

Table 6: **Number of Seedlings and Small Saplings per Hectare (number/ha) for Each Forest Stratum**

Strata	Trees per hectare (count/ha)					
	Seedlings (1.5 m tall to < 5.0 cm dbh)			Small Saplings (5 cm to <10.0 cm dbh)		
	Dipt.	Non Dipt.	Total	Dipt.	Non Dipt.	Total
1	142.61	2,046.21	2,188.81	10.47	408.19	418.66
2	188.92	1,799.72	1,988.64	7.46	346.77	354.23
3	145.83	1,672.67	1,818.50	15.47	381.16	396.62
4	160.99	1,441.76	1,602.75	22.49	329.07	351.56
5	94.11	1,613.99	1,708.10	22.19	306.29	328.48
6	79.85	1,224.82	1,304.67	12.05	307.34	319.39
7	59.66	1,438.04	1,497.69	12.43	319.43	331.85
8	125.40	1,421.73	1,547.13	3.71	395.50	399.21
9	154.22	1,864.86	2,019.08	28.41	351.06	379.47
10	96.59	1,218.75	1,315.34	11.36	373.58	384.94
11	53.86	1,369.68	1,423.53	5.80	178.98	184.78
12	141.81	1,605.58	1,747.40	4.08	138.55	142.63
13	79.31	2,127.73	2,207.04	7.69	238.52	246.21
14	39.17	1,443.27	1,482.44	13.56	295.28	308.84
15	6.91	1,390.67	1,397.57	2.76	382.54	385.30
16	110.80	1,782.67	1,893.47	11.36	311.08	322.44
17	29.24	1,213.66	1,242.90	2.92	231.03	233.96
18	26.17	376.79	402.96	0.00	91.58	91.58

Number of Trees

The results of the number of trees per hectare based on dipterocarp and non-dipterocarp groups for the entire strata are as shown in **Table 7**. According to the survey results, the number of trees per hectare for the diameter class > 10 cm dbh is 333.39 trees/ha, with the composition breakdown being 26.57 trees/ha for dipterocarps and 306.83 trees/ha for non-dipterocarps.

Table 7: **Number of Trees per Hectare (number/ha) by Diameter for All Strata**

Diameter (cm)	Dipterocarp (count/ha)	Non Dipterocarp (count/ha)	Total (count/ha)
≥ 10	26.57	306.83	333.39
≥ 15	20.87	229.15	250.02
≥ 30	8.18	51.11	59.29

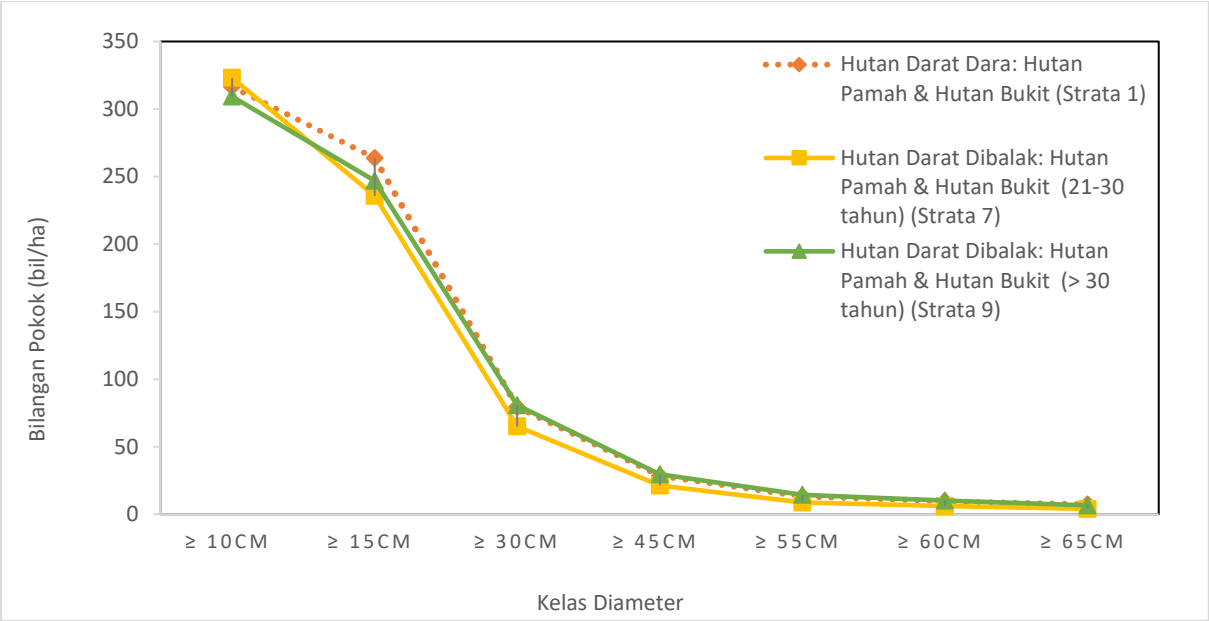
≥ 45	3.71	14.67	18.39
≥ 55	1.84	5.57	7.41
≥ 60	1.36	3.82	5.18
≥ 65	0.94	2.27	3.21

The survey results also found that Stratum 18 (Protected Forest: Mountain Forest) recorded the highest number of trees larger than 10 cm dbh, with 586.74 trees/ha. Details of the number of trees per hectare by diameter for Dipterocarps and Non-Dipterocarps for each forest stratum are as specified in **Tables 8**.

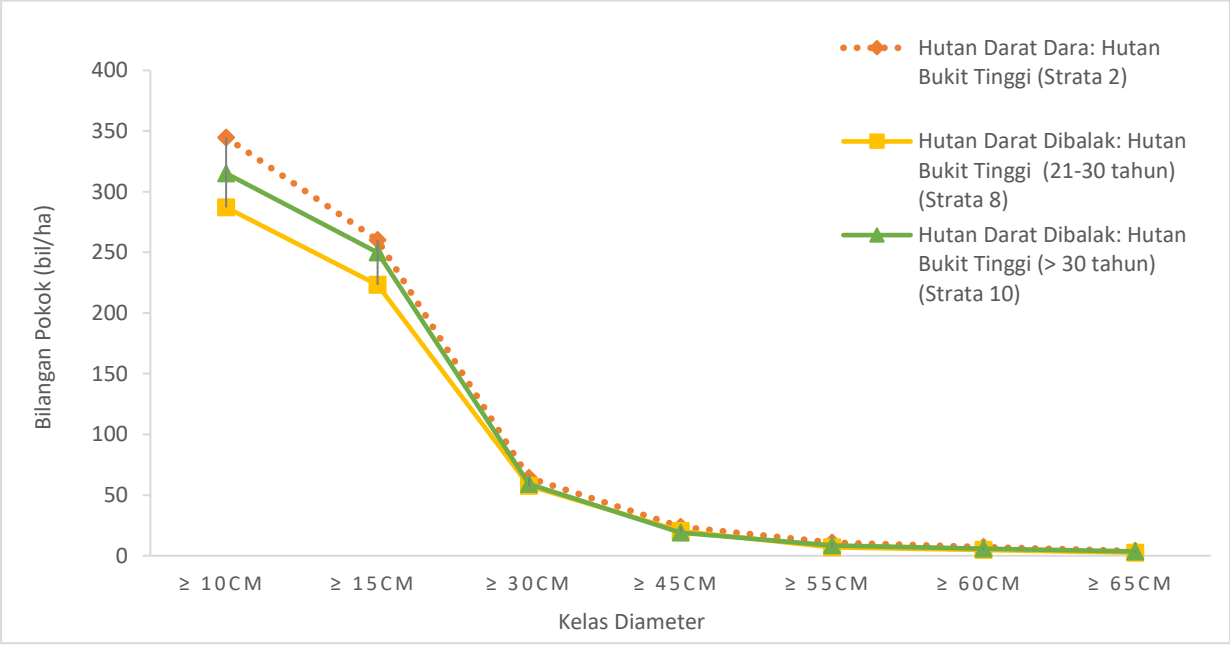
Table 8: **Number of Trees per Hectare (number/ha) by Diameter ≥ 10 cm, ≥ 30 cm, and ≥ 60 cm for Dipterocarps and Non-Dipterocarps in Each Forest Stratum**

Strata	Number of Tree (count/ha)								
	≥ 10 cm			≥ 30 cm			≥ 60 cm		
	Dipt.	Non Dipt.	Total	Dipt.	Non Dipt.	Total	Dipt.	Non Dipt.	Total
1	34.72	281.74	316.46	13.39	65.92	79.31	2.47	7.16	9.63
2	35.16	309.48	344.64	7.83	56.33	64.15	1.98	5.05	7.03
3	27.47	314.08	341.56	8.02	47.87	55.89	1.04	4.06	5.09
4	45.83	300.92	346.76	11.51	46.65	58.16	0.96	2.08	3.04
5	38.92	352.42	391.34	10.68	52.96	63.63	1.84	4.54	6.38
6	16.38	222.39	238.77	6.33	44.27	50.60	0.85	3.23	4.08
7	28.13	294.99	323.11	10.51	54.50	65.01	1.60	4.39	5.99
8	17.29	269.76	287.05	8.53	49.06	57.58	0.96	3.90	4.87
9	35.56	273.67	309.22	13.99	66.69	80.68	2.78	7.32	10.10
10	15.01	300.10	315.11	5.73	53.43	59.16	1.13	4.81	5.94
11	19.94	251.95	271.88	5.74	50.53	56.27	0.67	1.74	2.40
12	38.86	474.16	513.02	7.78	51.70	59.48	1.25	3.02	4.27
13	11.67	241.37	253.04	4.70	53.79	58.49	0.78	2.30	3.08
14	19.08	254.63	273.70	4.27	37.98	42.24	0.89	2.46	3.36
15	14.47	365.60	380.07	2.21	13.56	15.77	0.17	0.97	1.13
16	29.40	302.51	331.91	15.14	67.64	82.78	3.62	6.14	9.76
17	15.54	288.12	303.66	5.35	53.26	58.62	1.46	5.56	7.01
18	44.16	542.58	586.74	2.93	39.92	42.86	0.47	2.33	2.80

The comparison of the number of trees per hectare for Strata 1 (Virgin Lowland Forest: Lowland & Hill Forest), Strata 7 (Logged Lowland Forest: Lowland & Hill Forest (21-30 years)), and Strata 9 (Logged Lowland Forest: Lowland & Hill Forest over 30 years) shows that the number of trees in Strata 9 (Logged Lowland Forest: Lowland & Hill Forest over 30 years) is approaching the number of trees in Strata 1. The comparison for these three strata is illustrated in **Graph 1**. For Strata 2 (Virgin Upland Forest: High Hill Forest), Strata 8 (Logged Upland Forest: High Hill Forest (21-30 years)), and Strata 10 (Logged Upland Forest: High Hill Forest over 30 years), the number of trees is also similar, with tree distribution in Strata 10 approaching that of Strata 2. The comparison for these three strata is illustrated in **Graph 2**. The number of trees reflects that the forest areas being harvested are almost fully restored within the expected time frame, which is more than 30 years for Lowland and Hill Forests and more than 40 years for High Hill Forests.



Graph 1: Comparison of the Number of Trees per Hectare by Diameter for Strata 1, Strata 7 and Strata 9



Graph 2: Comparison of the Number of Trees per Hectare by Diameter for Strata 2, 8 and Strata 10

Tree Basal Area

The results of the tree basal area per hectare by diameter for the entire strata, categorized by Dipterocarps and Non-Dipterocarps, are as reported in **Table 9**. According to the results, the basal area for trees with a diameter >10 cm dbh per hectare is 16.82 m²/ha.

Table 9: **Basal Area per Hectare (m²/ha) by Diameter for All Strata**

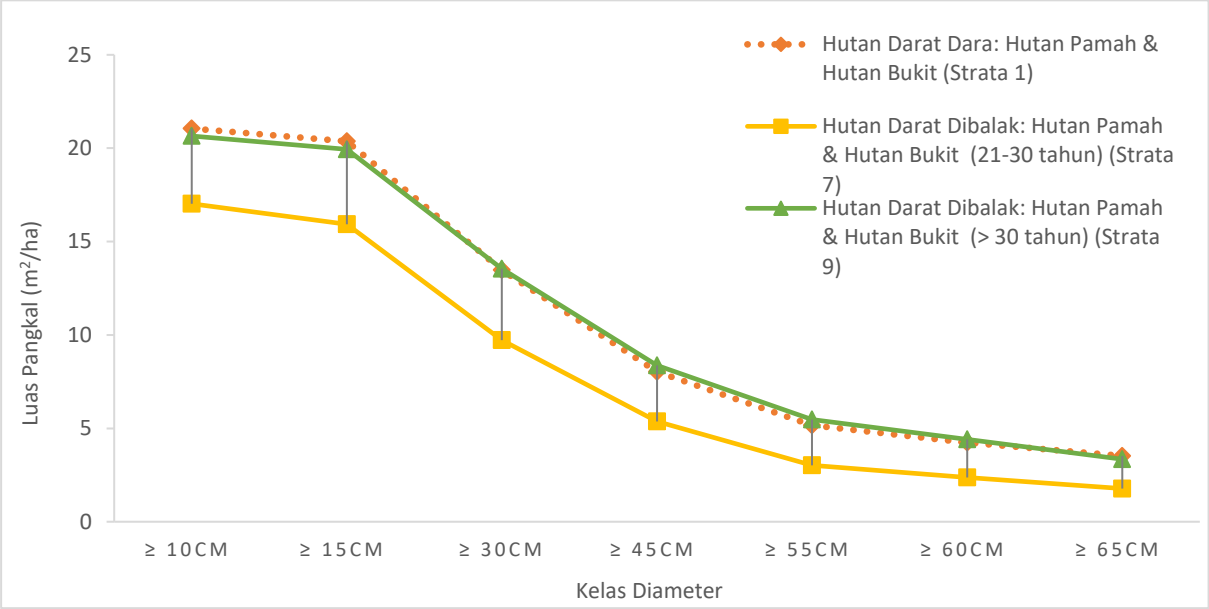
Diameter (cm)	Dipterocarp (m²/ha)	Non Dipterocarp (m²/ha)	Total (m²/ha)
≥ 10	2.08	14.74	16.82
≥ 15	2.01	13.80	15.82
≥ 30	1.56	7.44	9.00
≥ 45	1.08	3.70	4.78
≥ 55	0.72	1.99	2.72
≥ 60	0.60	1.55	2.15
≥ 65	0.47	1.09	1.56

For the tree basal area by forest stratum, the recorded results are as shown in **Table 10**. The basal area for Stratum 1 (Primary Lowland Forest: Lowland Forest & Hill Forest) is recorded as 21.05 m²/ha, which is lower than the basal area for Stratum 16 (Protected Forest: Lowland Forest & Hill Forest) at 21.77 m²/ha.

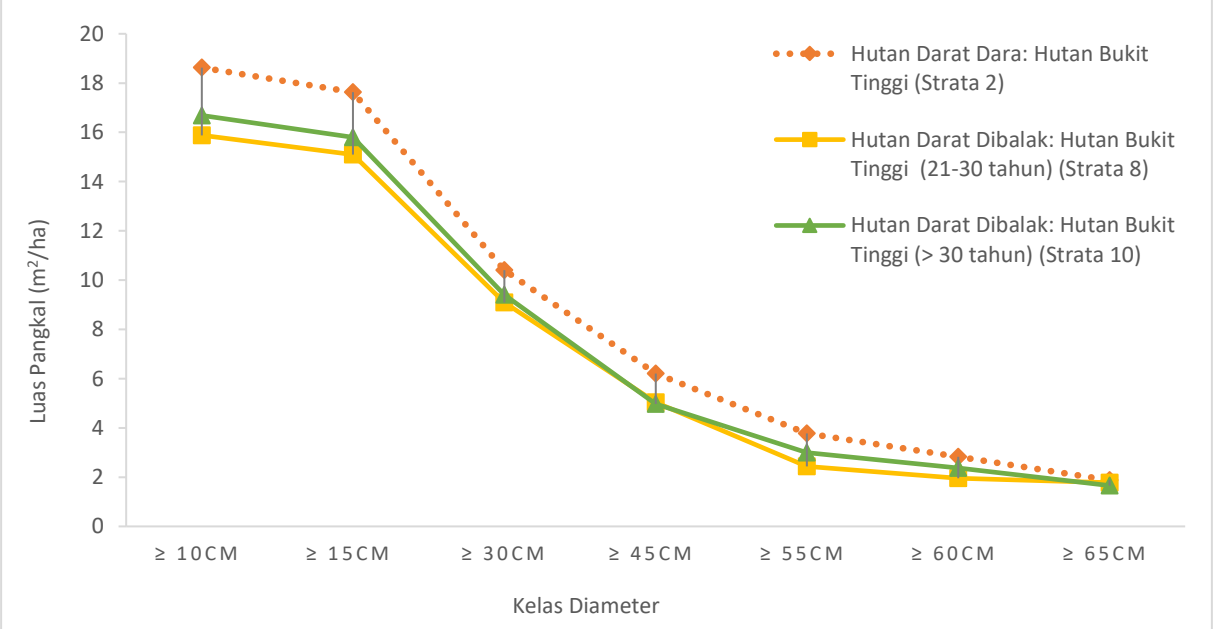
Table 10: **Basal Area per Hectare (m²/ha) by Diameter ≥ 10 cm, ≥ 30 cm, and ≥ 60 cm for Dipterocarps and Non-Dipterocarps in Each Forest Stratum**

Strata	Tree Basal Area (m²/ha)								
	≥ 10 cm			≥ 30 cm			≥ 60 cm		
	Dipt.	Non Dipt.	Total	Dipt.	Non Dipt.	Total	Dipt.	Non Dipt.	Total
1	3.16	17.89	21.05	2.63	10.84	13.47	1.16	3.08	4.24
2	2.43	16.20	18.63	1.80	8.60	10.40	0.93	1.90	2.83
3	2.02	15.42	17.44	1.49	7.49	8.98	0.49	1.80	2.29
4	2.79	13.52	16.31	1.90	6.31	8.21	0.48	0.93	1.40
5	2.71	15.73	18.45	1.96	7.79	9.75	0.73	1.79	2.52
6	1.45	11.88	13.33	1.15	6.58	7.73	0.42	1.24	1.67
7	2.50	14.53	17.03	1.95	7.78	9.73	0.65	1.73	2.38
8	1.79	14.09	15.88	1.52	7.57	9.09	0.40	1.55	1.96
9	3.80	16.86	20.65	3.02	10.53	13.55	1.37	3.04	4.41
10	1.29	15.40	16.69	1.06	8.34	9.40	0.43	1.94	2.37
11	1.43	12.80	14.23	0.98	6.15	7.13	0.28	0.68	0.97
12	2.20	16.48	18.67	1.38	6.97	8.34	0.57	1.16	1.74
13	1.10	14.24	15.33	0.87	7.27	8.14	0.29	0.90	1.19
14	1.36	11.09	12.45	0.91	5.15	6.06	0.42	1.03	1.45
15	0.53	11.03	11.56	0.25	1.86	2.11	0.06	0.36	0.42
16	3.86	17.91	21.77	3.29	10.34	13.63	1.60	2.66	4.26
17	1.41	13.76	15.18	1.18	7.88	9.06	0.65	2.18	2.82
18	1.74	15.84	17.58	0.53	5.32	5.84	0.16	0.89	1.05

Based on the results, the comparison of tree basal area per hectare for Strata 1 (Virgin Lowland Forest: Lowland & Hill Forest), Strata 7 (Logged Lowland Forest: Lowland & Hill Forest (21-30 years)), and Strata 9 (Logged Lowland Forest: Lowland & Hill Forest over 30 years) is shown in **Graph 3**, while the comparison of tree basal area between Strata 2 (Virgin Upland Forest: High Hill Forest), Strata 8 (Logged Upland Forest: High Hill Forest (21-30 years)), and Strata 10 (Logged Upland Forest: High Hill Forest over 30 years) is shown in **Graph 4**. Both graphs indicate that the basal area results for the respective strata are almost equivalent and have recovered.



Graph 3: Comparison of the Tree Basal Area per Hectare by Diameter for Strata 1, 7 and Strata 9



Graph 4: Comparison of the Tree Basal Area per Hectare by Diameter for Strata 2, Strata 8 and Strata 10

Tree Volume

The results for tree volume per hectare by diameter for Dipterocarp and Non-Dipterocarp groups across all strata are as reported in **Table 11**. Based on the results, the tree volume per hectare for trees with a diameter >10 cm dbh is recorded at 170.22 m^3/ha.

Table 11: **Volume per Hectare (m³/ha) by Diameter for All Strata**

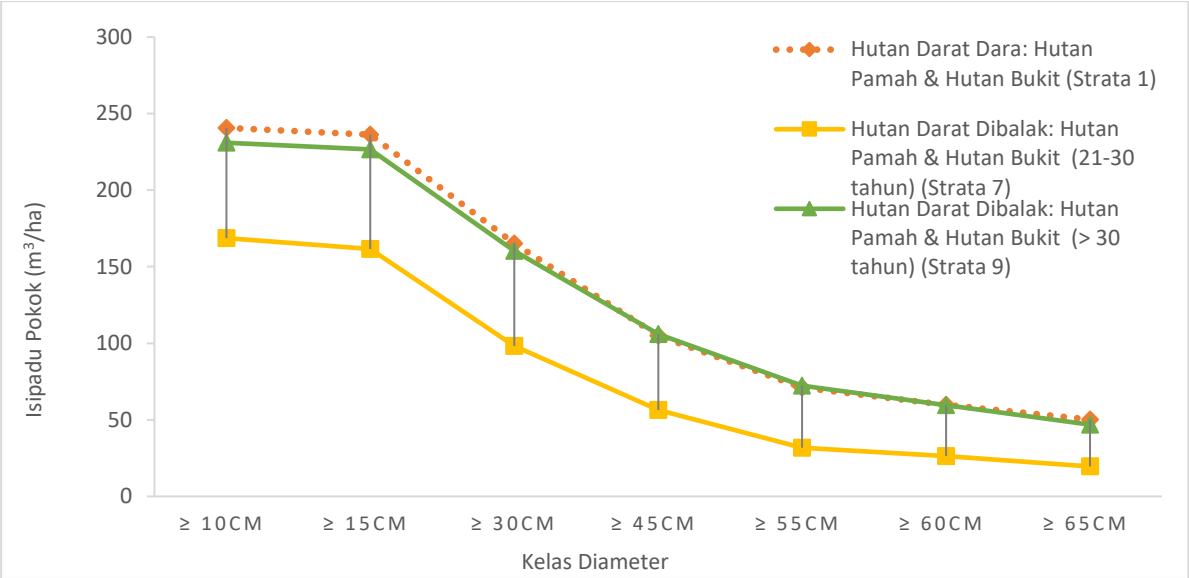
Diameter (cm)	Dipterocarp (m³/ha)	Non Dipterocarp (m³/ha)	Total (m³/ha)
≥ 10	23.35	146.87	170.22
≥ 15	22.92	140.92	163.84
≥ 30	18.31	76.07	94.38
≥ 45	13.55	41.93	55.48
≥ 55	9.69	24.01	33.69
≥ 60	8.26	19.18	27.44
≥ 65	6.64	13.78	20.42

Detailed information on tree volume per hectare by diameter for Dipterocarp and Non-Dipterocarp groups for each forest stratum is as shown in **Tables 12**. Stratum 1 (Primary Forest: Lowland Forest & Hill Forest) shows the highest recorded volume, which is 240.68 m³/ha.

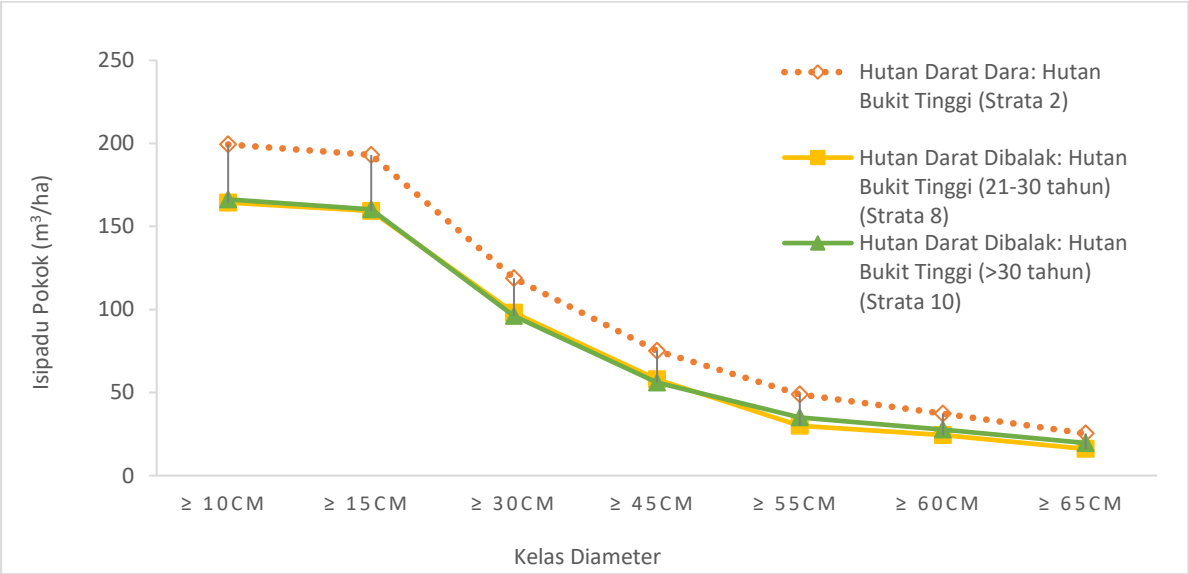
Table 12: **Volume per Hectare (m³/ha) by Diameter ≥ 10 cm, ≥ 30 cm, and ≥ 60 cm for Dipterocarps and Non-Dipterocarps in Each Forest Stratum**

Strata	Tree Volume (m³/ha)								
	≥ 10 cm			≥ 30 cm			≥ 60 cm		
	Dipt.	Non Dipt.	Total	Dipt.	Non Dipt.	Total	Dipt.	Non Dipt.	Total
1	40.70	199.98	240.68	35.76	129.33	165.10	17.65	42.11	59.76
2	30.49	168.89	199.38	24.84	94.09	118.93	14.19	23.08	37.27
3	24.46	163.15	187.62	19.36	85.53	104.89	7.38	23.04	30.41
4	31.96	140.29	172.24	23.76	70.56	94.31	7.10	12.49	19.59
5	29.25	160.56	189.81	22.20	85.17	107.37	9.70	21.81	31.52
6	14.42	118.00	132.42	11.44	66.16	77.60	5.21	15.50	20.71
7	25.81	142.87	168.68	20.39	77.81	98.19	7.09	19.22	26.31
8	20.61	143.77	164.38	17.96	80.05	98.02	5.75	18.72	24.47
9	46.79	184.19	230.98	38.85	121.57	160.42	19.73	39.84	59.57
10	14.49	151.82	166.31	12.34	83.74	96.08	4.84	22.83	27.67
11	12.56	111.15	123.71	8.09	44.28	52.37	3.68	7.20	10.88
12	19.98	148.97	168.95	12.20	63.38	75.58	6.97	12.86	19.82
13	13.24	137.33	150.56	10.96	65.16	76.12	4.26	12.47	16.73
14	15.92	103.14	119.05	11.41	46.39	57.80	6.04	9.32	15.35
15	4.97	99.77	104.74	2.46	14.14	16.60	0.77	3.70	4.47
16	44.05	186.77	230.82	38.02	111.28	149.30	20.89	33.82	54.70
17	14.68	135.31	149.99	12.57	80.35	92.92	8.34	27.96	36.30
18	17.45	144.33	161.78	5.55	52.15	57.70	1.95	10.26	12.20

The comparison of tree volume per hectare for Strata 1 (Virgin Lowland Forest: Lowland & Hill Forest) with Strata 9 (Logged Lowland Forest: Lowland & Hill Forest over 30 years) is shown in **Graph 5**. Meanwhile, the comparison of tree volume for Strata 2 (Virgin Upland Forest: High Hill Forest) with Strata 10 (Logged Upland Forest: High Hill Forest over 30 years) is shown in **Graph 6**. Both graphs indicate that the tree volume content for these respective strata is almost the same.



Graph 5: Comparison of the Tree Volume per Hectare by Diameter for Strata 1, 7 and Strata 9



Graph 6: Comparison of the Tree Volume per Hectare by Diameter for Strata 2, Strata 8 and Strata 10

Carbon Stock

Carbon stock (C) is the total amount of living organisms in a specific area, measured as biomass, either in a living or dead state. In ecology, it refers to the mass or weight of living material in a habitat.

In forestry, carbon stock refers to the amount of carbon stored in forests, mainly in living trees and organic material in the soil. Carbon is also stored in deadwood and forest litter (leaves and twigs) on the forest floor. These are called carbon reservoirs and are measured in metric tons (t C) or Megagrams (Mg C). There are five types of carbon reservoirs: (i) aboveground carbon, (ii) belowground carbon, (iii) deadwood carbon, (iv) forest litter carbon, and (v) soil organic carbon. However, this report only covers four types: aboveground, belowground, deadwood, and forest litter carbon.

Table 13 shows the total estimated carbon stocks achieved in NFI-6. An average is not provided for this parameter because it would not accurately reflect the total carbon stock based on the different forest strata in Peninsular Malaysia.

Table 13: Estimated Carbon Stock per Hectare (t C/ha) for Each Forest Stratum

Strata	Estimated Carbon Stock per Hectare (t C/ha)			
	Above and below ground	Dead wood	Forest Litter	Total
1	148.56	13.57	3.29	165.42
2	125.85	4.36	2.90	133.11
3	115.79	9.16	2.78	127.73
4	105.44	6.40	2.39	114.23
5	121.10	9.37	2.39	132.86
6	89.87	1.56	2.69	94.12
7	113.80	6.04	3.23	123.07
8	106.94	12.40	2.78	122.12
9	146.70	15.83	2.53	165.06
10	111.63	18.85	3.03	133.51
11	73.84	5.27	1.93	81.04
12	93.78	9.28	4.31	107.37
13	80.07	20.31	2.22	102.60
14	80.18	15.28	3.24	98.70
15	56.68	26.81	3.02	86.51
16	152.51	6.13	3.09	161.73
17	102.52	1.23	1.90	105.65
18	102.22	0.00	1.90	104.12

Medicinal Plants

The survey results found that Kacip Fatimah is the most frequently recorded medicinal plant, with 15.98 trees/ha, while Payung Ali is the least recorded, with 0.13 trees/ha. **Table 14** shows the number of medicinal plants per hectare across all strata.

Table 14: Medicinal Plants per Hectare (number/ha) for All Strata

Spesies	Medicinal Plants per hectare (count/ha)
Tongkat Ali	9.57
Kacip Fatimah	15.98
Tongkat Haji Samad	2.20
Hempedu Beruang	3.40
Gajah Beranak	2.77
Keladi Murai	1.95
Alek Besi / Alek Tembaga	0.19
Ubi Jaga	0.25
Lemba	5.41
Sepit	1.13
Payung Ali	0.13
Lekir	0.50

Rattan

The survey results found that Manau rattan is the most commonly encountered type, with 7.37 stems/ha. Dok rattan is the least encountered type, with 0.25 clumps/ha. **Table 15** shows the number of rattan stems/clumps per hectare by species across all strata.

Table 15: Number of Rattan Stems/Tufts per Hectare (number/ha) by Species for All Strata

Spesies	Number of Rattan stems/clumps per hectare (count/ha)
Manau*	7.37
Manau tikus*	0.53
Dok	0.25
Dahan	0.36
Sega	2.26
Semambu	0.38

Note: * Calculated based on the number of stems

Bamboo

The survey results found that Semantan bamboo is the most commonly encountered species, with 1.84 clumps/ha. Dinding bamboo is the least encountered species, with 0.12 clumps/ha. **Table 16** shows the number of bamboo clumps per hectare by species across all strata.

Table 16: Number of Bamboo Clumps per Hectare (clumps/ha) by Species for All Strata

Spesies	Number of Bamboo Clumps per Hectare (clumps/ha)
Semantan	1.84
Beti	0.28
Beting	0.04
Betong	0.68
Semeliang	0.28
Dinding	0.12

Palm

The survey results found that Kelubi is the most commonly encountered palm species, with 7.97 clumps/ha. Serdang is the least encountered palm species, with 0.07 stems/ha. **Table 17** shows the number of palm stems/clumps per hectare by species across all strata.

Table 17: Number of Palm Stems/Tufts per Hectare (number/ha) by Species for All Strata

Spesies	Number of Palm Clumps per hectare (count/ha)
Bertam	7.00
Bayas*	0.94
Nibung*	0.52
Serdang*	0.07
Ibol*	0.03
Enau*	0.28
Kelubi	7.97
Salak	0.36

Note: * Calculated based on the number of stems

DISCUSSION

The Sixth National Forest Inventory (NFI-6) is a key tool for gathering data on forest management. It provides up-to-date information on forest conditions and composition in Peninsular Malaysia, which helps in planning and managing forest resources effectively. The data allows for accurate assessments of forest stands to support planning and strategy development for forest management.

The average number of trees in Peninsular Malaysia's forests is 333.39 per hectare. For trees larger than 30 cm, there are 59.29 trees per hectare. Specifically, in Stratum 1 (Primary Forests: Lowland & Hill Forests), there are 79.31 trees per hectare for those larger than 30 cm. In Stratum 9 (Logged Forests: Lowland & Hill Forests, over 30 years), there are 80.68 trees per hectare of that size. This is higher than in Stratum 1. For Stratum 3 (Logged Forests: Lowland & Hill Forests, 1-10 years), there are 55.89 trees per hectare. These figures show that forest stands, whether logged recently or long ago, have good stock and meet the minimum requirement of 32 marketable trees. This ensures future harvesting cycles have enough stock. Since 1978, the Selective Management System (SMS) has improved forest management with various guidelines and practices to ensure quality and quantity of forest resources.

NFI-6 data shows the average tree volume in Peninsular Malaysia's forests is 170.22 m^3/ha. For trees larger than 30 cm, the volume is 94.38 m^3/ha, and for those larger than 45 cm, it's 55.48 m^3/ha. These volumes exceed the economic threshold of 30-40 m^3/ha for logging. In Stratum 9, the volume is close to the original forest volume of 106.07 m^3/ha. Stratum 3 has a volume of 63.28 m^3/ha.

The NFI-6 analysis shows that forests in Strata 7 and 8, aged 21 to 30 years, are still on track to achieve optimal results similar to Strata 1 and 2. However, factors like natural disturbances, human impact, and incomplete post-harvest treatments can affect these results. Examples include landslides, forest fires, climate change, pathogen infections, and illegal logging. Post-harvest treatments usually take about 10 years to ensure full recovery and involve activities like replanting, clearing, and thinning.

NFI-6 also tracks forest carbon stocks, which include aboveground, belowground, dead wood, and forest litter carbon. The estimated carbon stock is 119.94 t C/ha. According to Hamdan et al., 2023, carbon stock ranges from 56.30 to 158.20 t C/ha for dryland forests and 30.20 to 107.70 t C/ha for peat swamp forests.
From 2010 to 2023, climate events like El Niño and La Niña have significantly impacted weather patterns, including in Malaysia. The 2015–2016 El Niño was particularly strong, leading to higher temperatures and less rain. These events affect tree growth, with El Niño causing droughts and La Niña increasing rainfall, impacting tree survival and growth.

The NFI-6 survey shows that Peninsular Malaysia's forests are still rich in non-timber products and medicinal plants. The highest numbers recorded are for manau rattan, semantan bamboo, and kelubi palm. The most common medicinal plant recorded is Kacip Fatimah.

Overall, NFI-6 provides a good picture of the state of forests in Peninsular Malaysia, especially those that have been managed. To keep the inventory relevant, several improvements can be made:

a) **Review Methods:** Update inventory methods to match current forestry needs.
b) **Training:** Create a specialized team for the inventory with continuous training.
c) **Use of Technology:** Incorporate technologies like LiDAR, drones, and AI for better planning and fieldwork.
d) **Data Management:** Develop efficient systems for storing and analyzing inventory data.
e) **Ongoing Monitoring:** Continuously monitor and evaluate the effectiveness of measures and make improvements as needed.

CONCLUSIONS

The results from NFI-6 show that the selective management system used in production forests is effective. The J-Song Curve data indicate that forests can recover to nearly their original state after 30 years. The inventory also reveals that non-timber forest resources are still present in Peninsular Malaysia's forests. However, the Department needs to address species distribution and implement mitigation measures.

While the NFI-6 report is generally positive and supports the Sustainable Forest Management practices in Peninsular Malaysia, there are areas for improvement. These include refining the inventory methods, using up-to-date technology, and enhancing team training. It's also suggested that the NFI be included as a training module within the Department to better introduce and apply it. The information from NFI-6 can help the Department plan and manage forests more effectively for sustainability.

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