J. Viet. Env. **2016**, Vol. 8, No. 2, pp. 88-94
DOI: 10.13141/jve.vol8.no2.pp88-94

JOURNAL of VIETNAMESE ENVIRONMENT

Study on biomass and carbon stock of woody floor at several forests in Bach Ma national park, Thua Thien Hue province

Nghiên cứu sinh khối và trữ lượng carbon của tầng cây gỗ ở một số trạng thái rừng thuộc vườn quốc gia Bạch Mã, tỉnh Thừa Thiên Huế

Research article

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The aims of the research are to identify biomass and estimate carbon stock of woody floor at some forest status in Bach Ma National Park and to recommend some solutions in order to improve the effectiveness of forest management toward sustainable development. Collecting the relative data through articles, books, internet information and organizations and inheriting the data from previous research on biomass and carbon stock. Moreover, the research implemented field surveys by designing 31 circular plots (1,256 m^2) with three radii including 4 m, 14 m and 20 m for measuring trees from 5 to 20 cm, 20-50 cm and > 50 cm DBH (diameter at breast height), respectively. Correspondingly, $D_{1.3}$, H were measured. The results showed that biomass of rich, medium and restoration forests are 144.16, 43.17 and 20.31 ton/ ha, respectively. The total average C-stock is calculated as follows: rich forest 264.53 (ton/ha), medium forest (79.21 ton/ha) and restoration forest (37.27 ton/ha). Therefore, the rich forest has the highest CO_2 absorption (399.78 ton/ha). Meanwhile, CO_2 absorption of medium and restoration forests are 133.13 ton/ha and 46.81 ton/ha.

Mục tiêu của đề tài là nghiên cứu sinh khối và trữ lượng carbon của tầng cây gỗ tại một số trạng thái rừng thuộc vườn quốc gia Bạch Mã, tỉnh Thừa Thiên Huế. Để thực hiện được mục tiêu đó, đề tài cần xác định sinh khối của tầng cây gỗ ở một số trạng thái rừng tại vườn quốc gia Bạch Mã, đánh giá trữ lượng carbon của tầng cây gỗ ở một số trạng thái rừng tại vườn quốc gia Bạch Mã, đề xuất một số giải pháp nhằm nâng cao hiệu quả quản lý rừng theo hướng phát triển bền vững. Đề tài tiến hành thu thập các số liệu có liên quan bằng cách tham khảo tài liệu từ sách báo, internet, tìm kiếm thông tin từ các cơ quan, ban ngành, kế thừa số liệu từ các công trình nghiên cứu sinh khối và trữ lượng carbon. Bên cạnh đó, đề tài còn thực hiện quá trình đi điều tra thực địa lập 31 ô tiêu chuẩn, mỗi ô tiêu chuẩn có diện tích là 1256m^2, ô tiêu chuẩn hình tròn với 3 cấp bán kính là 4m, 14m, 20m tương ứng với đường kính cây lần lượt là 5-20cm, 20-50cm và lớn hơn 50 cm. Tiến hành đo các chỉ số sinh trưởng của cây là $D_{1.3}$, H_{vn}. Kết quả nghiên cứu cho thấy sinh khối trạng thái rừng giàu chiếm khối lượng lớn nhất khoảng 144,16 tấn/ha, tiếp đến là trạng thái rừng trung bình chiếm 43,17 tấn/ha và rừng phục hồi là 20,31 tấn/ha. Đối với trữ lượng carbon thì rừng giàu là 264,53 tấn/ha, rừng trung bình là 79,21 tấn/ha, rừng phục hồi là 37,27 tấn/ha. Xét về khả năng hấp thụ CO_2 thì trạng thái rừng giàu là hấp thụ nhiều nhất khoảng 399,78 tấn/ha, thấp nhất là rừng phục hồi với 46,81 tấn/ha, còn rừng trung bình là 133,13 tấn/ha.

Keywords: biomass, stock, CO2, forest, Bach Ma National Park

1. Introduction

Currently, the greenhouse gas emission is one of the most important issues in worldwide, particularly CO_2 from deforestation and forest degradation. Tropical deforestation is estimated from 1 to 2 billion tons of CO2 emission per year (Fearnside and Laurance, 2004; Houghton, 2005; Malhi, 2000). According to FAO (2005), the sources of greenhouse gas emission in the most of the tropical countries are coming from deforestation and forest degradation.

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http://dx.doi.org/10.13141/JVE
ISSN: 2193-6471

In Vietnam, several research has been focusing on biomass and carbon stock of natural forests which aim to propose the economic effect of the forest as well as a carbon credit. Payment for environmental service (PES), especially REDD (Reduce Emission off Deforestation and Degradation) is an efficient way for buying C stock in protected areas. To meet this, protected areas need to measure how much carbon stocked in their forest and show the degradation in forest over decades (BMNP, 2014).

Bach Ma National Park (BMNP) was established in 1991 in order to stop over-exploitation and enhance of storage ability of biodiversity and carbon stock. However, BMNP has been facing to forest degradation caused by illegal logging, so maintaining the management mechanism of carbon monitoring is still difficult. Therefore, the assessment of the growth level of general timber quality and carbon stock in specific are the first purposes in this protected area. The aim of this research is to assess the change of forest quality through monitoring biomass and carbon stock of forest floor by using satellite image analysis as well as combination with the circle plot survey according to Karren's method (2014).

2. Materials and methodologies

2.1. Overview of study site

BMNP consists of 42 sub-regional forests with the total area of 37,487 ha which is located in Central Vietnam. It was established in 1991 (34,380 ha belonging to Thua Thien Hue province and 3,107 belonging to Quang Nam Province). The restricted area is 12,065 ha, the ecological recovery area is 20,324 ha and administrative service area is 5,188 ha (FIPI, 2006). The buffer zone includes 17 communes and towns with the total area of 58,676 ha. Around 25,257 households are living in the buffer zone of BMNP with a total population of over 79,000 people. Most people in the buffer zone are Kinh (84.13%), KaTu (15.15%), Van Kieu (0.68%), Muong (0.04%) ethnics (BMNP, 2008). The highest population density is 790 people/ km^2 and the lowest is 10 people/ km^2. The average density in the whole area of the park is around 159 people /km^2 (FIPI, 2006). In some remote villages near core zone of the park, a number of poor households is high and local people must depend on forest products. For this reason, the illegal hunting still happens even for trading. The need for timber of each household was estimated around 0.4m^3/year and firewood is 8.5 steer/ household/ year (BMNP, 2014).

2.2. Research methodologies

2.2.1. Survey, collect data and data analysis

Collecting the land-use map, DEM, forest resource map through 2000, 2010 and 2015 in study site; Finding the previous research relating to biomass and carbon stock; Searching on documents relating to natural conditions of the study site, forest management and protect. We used Excel for data analysis and SPSS to identify the relationship among forest biomass in plots.

2.2.2. Method for identifying forest biomass in the field

There are a lot of methodologies which are used to define the real biomass of forest. However, in this research, the plots were established responding to each forest status as following steps:

a. *Designation of plots:* 31 circle plots represented for three basic forest status of BMNP including Rich forest (11 plots), Medium forest (10), Restoration forest (10 plots).

b. *Establishment of plots:* According to "Training of trainers" manual of RECOFTC and Karen et al. (2014) together with field survey of study sites, we designed circle plots (1,256 m^2) with three radius including 4 m, 14 m and 20 m for measuring trees from 5 to 20 cm, 20-50 cm and > 50 cm DBH (diameter at breast height), respectively.

c. *Collecting data at each plot:* Objective research is woody plants with criteria:

- DBH (diameter at breast = $D_{1.3}$, cm) by measuring $C_{1.3}$ for tree > 5cm in DBH.
- H (Height, m) is measured by Blumer Leiss for all of the trees with higher 5cm.
- Elevation and coordination are measured by GPS;
- Calculating and defining biomass according to Brown (1997) as formula:
  $AGB=EXP(-3,1141+0,9719*Ln(D^2*H))(ton/ ha)$.

Where: AGB: Above Ground Biomass; D: diameter at breast (cm); H (height, m).

2.2.3. Method for identifying carbon stock

According to IPCC (2003), Carbon stock will be measured by default coefficient with dried biomass:

$$CBS = 0.5 * TAB. (ton/ha).$$

Where: CBS: Carbon stock;

TAB: Total Above Biomass (TAB = AGB + BGB (Below Ground Biomass))

CO_2 Stock: $CO_2 = 3.67 * CBS$

Notes: In this method, TAB = AGB (BGB was not calculated).

3. Results and discussions

3.1. The characteristics of forest status

3.1.1. Rich forest

In the rich forest, a total of 51 tree species (6 unidentified) were recorded belonging to 25 families. Tree species in this type of forest develop strongly such as *Parashorea stellata, Dipterocarpus hasseltii*, *Pometia pinnata, Castanopsis sp., Syzygium sp.* with the average diameter of 29 cm. Generally, trees with diameter higher 25 cm dominate at a high rate, followed by the trees with a diameter of 20-25 cm and lower 20 cm. Correspondingly, the height of the tree in this

forest can peak at up to over 40 m and the average height of 15.1 m (Figure 1, appx. 1).

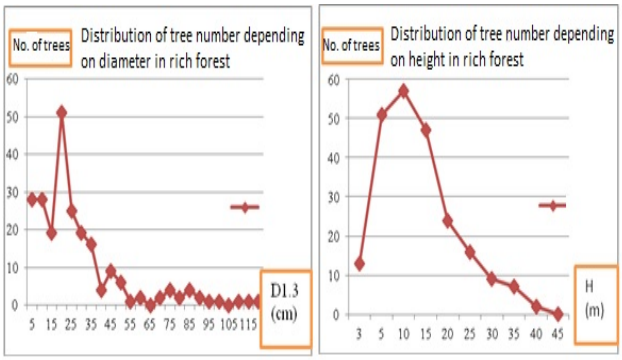

Figure 1. The distribution of tree number depending on diameter and height in rich forest

3.1.2. Medium forest

This type of forest distributes mainly at an elevation below 500 m and species composition is lower comparing to the rich forest. However, this forest is quite abundant with high economic species including *Syzygium sp., Sindora tonkinensis, Pometia sp.* etc. A total of 26 tree species was surveyed belonging mainly to families: Dipterocarpaceae, Fabaceae and Fagaceae. The average diameter of the medium forest is approximately 23 cm which is divided into two levels including higher and lower 30 cm at the diameter. In which, the tree with a diameter below 30 cm occupies with a high number. Moreover, trees in this forest type can be divided into three levels at height: h < 5 m, 5< h < 15 m and > 15 m. The number of timber trees from 5 to 15 m in height dominated with the highest rate and the average height of trees in this forest status is 10.8 m (Figure 2).

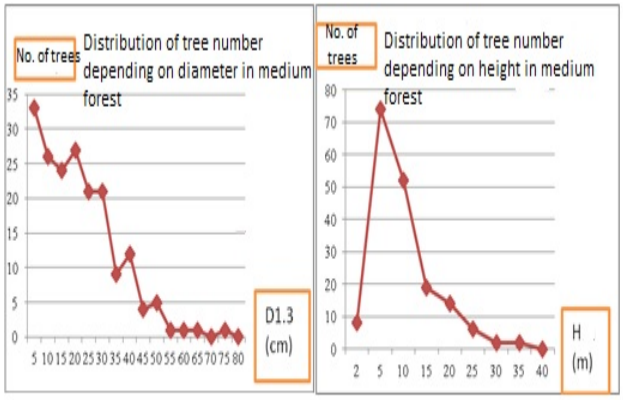

Figure 2. The distribution of tree number depending on diameter and height in medium forest

3.1.3. Restoration forest

Around 31 tree species were found in this type of forest belonging to 19 families such as Euphorbiaceae and Theaceae. Although species composition is not so abundant compared to the rich forest, the number of tree species is quite high (31 species) in comparison with medium forest. Generally, most of the trees are limited at diameter and height, mainly below 20 cm and 15 m, respectively (Figure 3).

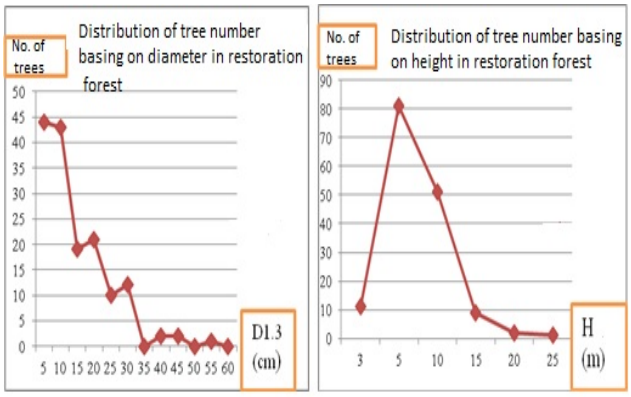

Figure 3. The distribution of tree number depending on diameter and height in restoration forest

3.2. Identifying biomass and carbon stock of the different forest status

3.2.1. Location of plots

31 circular plots (1,256 m^2) were randomly established in BMNP: 11, 10, 10 plots were located in the rich forest, medium forest and restoration forest, respectively. Each circular plot was designed with three radiuses including 4 m, 14 m, and 20 m for measuring timber trees from 5 to 20 cm, 20-50 cm and > 50 cm DBH (diameter at breast height), respectively (Figure 4).

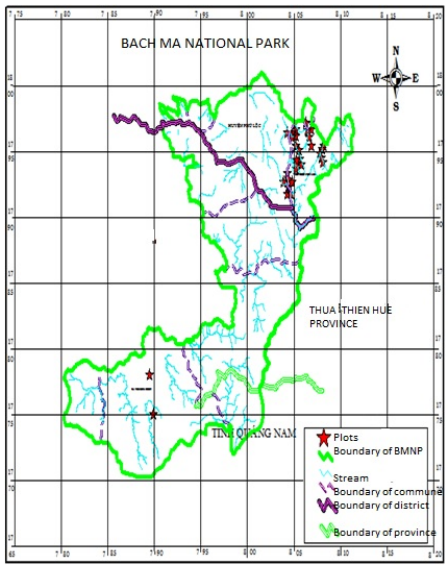

Figure 4. Map of location of 31 circle plots

3.2.2. Identifying biomass and carbon stock in different forest status

a. Rich forest

11 circular plots were surveyed in the rich forest including 9 lots in Phu Loc district and 2 plots in Nam Dong district in Thua Thien Hue province (Table 1). The result showed that biomass in most of the plots was very high with an average of 144.16 ton/ ha and 264.53 ton CO_2 stock/ ha. However, there was a significant distinction of biomass among plots such as 377.38 ton/ha in plot 24, whereas only 14.63 ton/ ha in plot 21.

Table 1. Biomass of plots in rich forest

Plots	Coordinates		Bio-mass (ton/ ha)	CO_2 stock (ton/ ha)
	X	Y		
16	805184	1795501	168.75	309.66
17	805498	1795135	48.08	88.23
18	805761	1794080	48.53	89.05
19	805610	1794494	54.19	99.44
21	805217	1793711	14.63	26.85
23	804285	1793378	58.90	108.08
24	803888	1792698	377.38	692.49
25	804479	1792882	347.06	636.86
26	804780	1792756	77.12	141.52
27	804369	1792285	174.29	319.82
31	789885	1775100	216.84	397.90
Average			**144.16**	**264.53**

b. Medium forest

10 circular plots were designed in medium forest belonging to Phu Loc district – Thua Thien Hue province (table 2). The result showed that biomass and CO_2 stock among plots were quite equal and fluctuated from 14.17 (plot 9) to 69.33 (plot 6) ton/ ha and 26 to 127.22 ton/ ha, respectively. It can be clearly seen that biomass of plots in the medium forest is absolutely low in comparison to the rich forest.

Table 2. Biomass of plots in medium forest

Plots	Coordinates		Biomass (ton/ ha)	CO_2 stock (ton/ ha)
	X	Y		
2	808162	1795485	19.32	35.45
4	808044	1795198	30.87	56.65
6	806876	1795479	69.33	127.22
7	807744	1794877	48.16	88.37
8	807926	1794587	55.46	101.77
9	808119	1794207	14.17	26.00
13	804825	1796450	47.69	87.51
14	804301	1796441	65.00	119.28
15	804814	1796128	65.00	119.28
22	805285	1794372	16.66	30.57
Average			**43.17**	**79.21**

c. Restoration forest

10 circular plots were researched in restoration forest in Phu Loc district, Thua Thien Hue province (table 3). In general, biomass in this type of forest is very low with an average of 20.31 ton/ ha and 37.27 ton CO_2 stock/ ha. The highest biomass concentrated in plot 20 (57.34 ton/ ha) and the lowest biomass in plot 11 with only 1.95 ton/ ha.

Table 3. Biomass of plots in restoration forest

Plots	Coordinates		Biomass (ton/ ha)	CO_2 stock (ton/ ha)
	X	Y		
1	806843	1796751	12.48	22.90
3	806447	1796632	13.39	24.57
5	806619	1796143	28.03	51.44
10	806264	1797212	32.43	59.51
11	805234	1796758	1.95	3.58
12	805231	1796230	12.14	22.28
20	805311	1794159	57.34	105.22
28	804298	1791843	24.66	45.25
29	804712	1798124	16.30	29.91
30	789494	1778084	4.41	8.09
Average			**20.31**	**37.27**

d. Assessment on biomass and CO_2 stock

Figure 5 showed that rich forest has higher amount of biomass comparing to medium and restoration forests. Particularly, biomass in rich forest reached at 144.16 ton/ ha, whereas biomass of medium and restoration forest were around 43.17 and 20.31 ton/ ha, respectively. It can be absolutely seen that biomass of the rich forest tripled compare with medium forest and approximately seven times in comparison with restoration forest. Although biomass of medium forest was higher than restoration forest, it was unequal the difference between rich forest and medium forest.

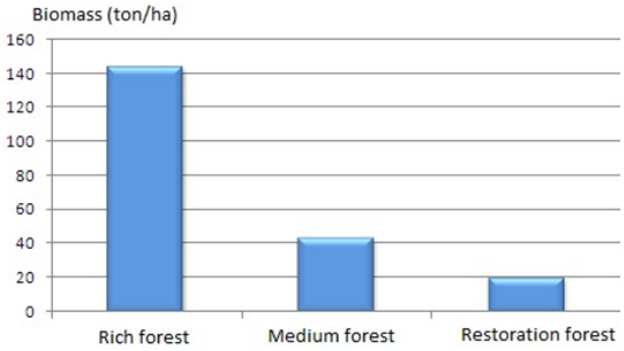

Figure 5. Biomass in three different types of forest

In each forest status, biomass value among plots also had high a fluctuation. For instance, in the rich forest, plot 24 had high valuable biomass (377.38 ton/ ha) compare to plot 21 with only 14.63 ton/ ha. Besides, in restoration forest, plot 20 also had highest biomass (57.33 ton/ ha), in which, on ly 1.95 ton/ ha in plot 11 in the same forest status. It can be explained that the designation of plots were not fully represented and it may affect to this difference.

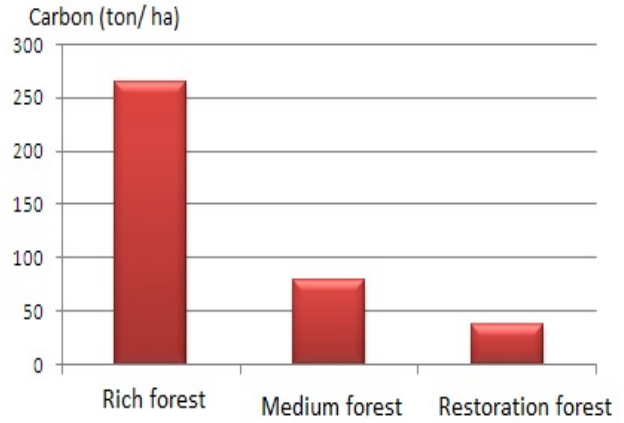

Figure 6. Carbon stock in three different types of forest

According to Figure 6, carbon stock in different types of forest had a high fluctuation. Particularly, there were many trees with high diameter and predominated height in rich forest with 264.53 tons of carbon stock per ha. Meanwhile, 79.21 ton/ ha for carbon stock in the medium forest and 37.27 ton/ ha in restoration forest. Therefore, from the amount of carbon stock in different types of forest, rich forest had highest amount and predominated compare to other forest status left. In conclusion, the carbon absorption ability of distinct forest types focused on rich forest.

3.2.3. Identifying CO_2 absorption ability of different forest types

Based on Table 4, it can be clearly seen that similar to biomass and carbon stock, the CO_2 absorption ability of rich forest predominated absolutely in comparison with two remaining other forest status. The medium forest had high CO_2 absorption ability, yet it was still limited compare to rich forest. Meanwhile, although restoration forest had lowest CO_2 stock, it has high potential in CO_2 absorption in the near future with suitable protection and technique.

Table 4. Absorption CO_2 content of three types of forests

Forests	Rich forest	Medium forest	Restoration forest
CO_2 (ton/ ha)	399.78	133.13	46.81

4. Conclusions

- In rich forest, species composition had high abundant including many big trees, so it had absolutely higher biomass than the other forest status.
- There was high discrepancy about carbon stock among forest status and plots, especially between rich forest and medium and restoration forests.
- Restoration forest had high potential in supplying biomass and carbon stock in the near future.
- It is very necessary in protecting and improving of sustainable forest management effect such as using suitable forest techniques and enhances forest protection in order to mitigate lost forest biomass.

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Appendix 1: Tree species in three forest types in Bach Ma National Park

No.	Tree species in rich forest	Family
1	*Alangium ridley*	ALANGIACEAE
2	*Amesiodendron chinense*	SAPINDACEAE
3	*Artocarpus rigidus*	MORACEAE
4	*Camellia chrysantha*	THEACEAE
5	*Camellia fleuryi*	THEACEAE
6	*Canarium album*	BURSERACEAE
7	*Canarium bengalensis*	BURSERACEAE
8	*Canarium sp.*	BURSERACEAE
9	*Castanopsis sp.*	FAGACEAE
10	*Cinnamomum burmannii*	LAURACEAE
11	*Cinnamomum cassia*	LAURACEAE
12	*Cinnamomum sp.*	LAURACEAE
13	*Dillenia Indica*	DILLENIACEAE
14	*Dipterocarpus alatus*	DIPTEROCARPACEAE
15	*Endospermum chinense*	EUPHORBIACEAE
16	*Eurycoma longifolia*	SIMAROUBACEAE
17	*Fagus sp.*	FAGACEAE
18	*Ficus racemosa*	MORACEAE
19	*Garcinia cochinchinensis*	CLUSIACEAE
20	*Garcinia merguensis*	CLUSIACEAE
21	*Gironniera subaequalis*	ULMACEAE
22	*Gordonia Axillaris*	THEACEAE
23	*Hura crepitans*	EUPHORBIACEAE
24	*Jatropha curcas*	DIPTEROCARPACEAE
25	*Knema conferta*	MYRISTICACEAE
26	*Knema pierrei*	MYRISTICACEAE
27	*Litsea glutinosa*	LAURACEAE
28	*Macropanax dispermus*	ARALIACEAE
29	*Magnolia officinalis*	MAGNOLIACEAE
30	*Melanorrhoea laccifera*	ANACARDIACEAE
31	*Nephelium lappaceum*	SAPINDACEAE
32	*Ormosia balansae*	FABACEAE
33	*Palaquium annamense*	SAPOTACEAE
34	*Parashorea chinensis*	SAPOTACEAE
35	*Parashorea stellata*	DIPTEROCARPACEAE
36	*Podocarpus neriifolius*	PODOCARPACEAE
37	*Pometia sp.*	SAPINDACEAE
38	*Scaphium lychnophorum*	STERCULIACEAE
39	*Schefflera octophylla*	ARALIACEAE
40	*Spondias lakonensis*	ANACARDIACEAE
41	*Strophanthus caudatus*	APOCYNACEAE
42	*Syplocos racemosa Roxb.*	SYPLOCACEAE
43	*Syzygium sp.*	MYRTACEAE
44	*Syzygium zeylanicum*	MYRTACEAE
45	*Tarrietia cochinchinensis*	STERCULIACEAE
No.	**Tree species in medium forest**	**Family**
1	*Alangium ridley*	ALANGIACEAE
2	*Amesiodendron chinense*	SAPINDACEAE
3	*Canarium sp.*	BURSERACEAE
4	*Cratoxylon pruniflorum*	HYPERICACEAE
5	*Croton oblongifolius*	EUPHORBIACEAE
6	*Elaeocarpus griffithii*	ELAEOCARPACEAE
7	*Endospermum chinense*	EUPHORBIACEAE
8	*Engelhardtia chrysolepis*	JUGLANDACEAE
9	*Euodia crassifolia*	RUTACEAE
10	*Euphorbia tirucalli*	EUPHORBIACEAE
11	*Fagus sp.*	FAGACEAE
12	*Gironniera subaequalis*	ULMACEAE
13	*Knema conferta*	MYRISTICACEAE
14	*Knema pierrei*	MYRISTICACEAE
15	*Nephelium cuspidatum*	SAPINDACEAE
16	*Parashorea chinensis*	DIPTEROCARPACEAE
17	*Sapium sebiferum*	EUPHORBIACEAE
18	*Schefflera octophylla*	ARALIACEAE
19	*Sindora tonkinensis*	FABACEAE
20	*Syplocos racemosa*	SYPLOCACEAE
21	*Syzygium sp.*	MYRTACEAE

No.	Tree species in recovery forest	Family
1	*Amesiodendron chinense*	SAPINDACEAE
2	*Camellia chrysantha*	THEACEAE
3	*Camellia fleuryi*	THEACEAE
4	*Canarium album*	BURSERACEAE
5	*Canarium tramdenum*	BURSERACEAE
6	*Cinnamomum burmannii*	LAURACEAE
7	*Cipadessa baccifera*	MELIACEAE
8	*Cratoxylon pruniflorum*	HYPERICACEAE
9	*Croton oblongifolius*	EUPHORBIACEAE
10	*Dacrydium pierei*	PODOCARPACEAE
11	*Engelhardtia chrysolepis*	JUGLANDACEAE
12	*Euphorbia tirucalli*	EUPHORBIACEAE
13	*Fagus sp.*	FAGACEAE
14	*Ficus variolosa*	MORACEAE
15	*Garcinia cochinchinensis*	CLUSIACEAE
16	*Gordonia axillaris*	THEACEAE
17	*Gordonia tonkinensis*	THEACEAE
18	*Knema pierrei*	MYRISTICACEAE
19	*Melanorrhoea laccifera*	ANACARDIACEAE
20	*Parashorea chinensis*	DIPTEROCARPACEAE
21	*Pinus dalatensis*	PINACEAE
22	*Podocarpus neriifolius*	PODOCARPACEAE
23	*Sapium discolor*	EUPHORBIACEAE
24	*Schefflera octophylla*	ARALIACEAE
25	*Syplocos racemosa*	SYPLOCACEAE
26	*Syzygium sp.*	MYRTACEAE