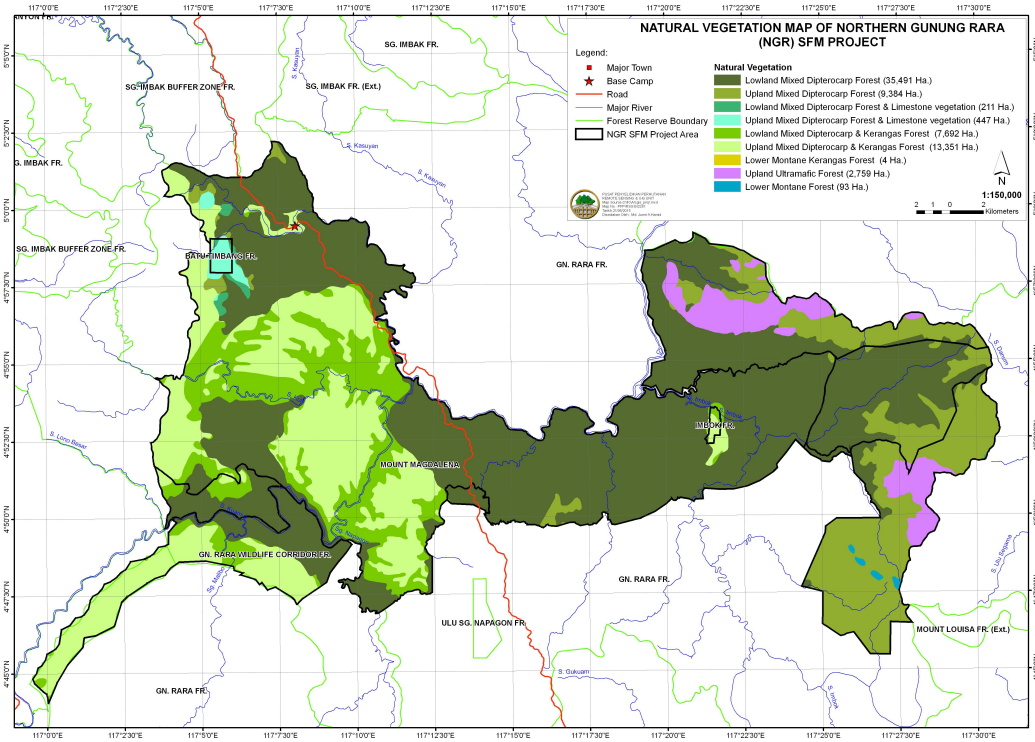
Report on Monitoring of forest changes 2015–2018 in Northern Gunung Rara Sustainable Forest Management Project Area



by

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SUMMARY

The Northern Gunung Rara Sustainable Forest Management Project Area covering 69,777.36 ha of totally protected area, comprises seven forest reserves, i.e. Mt Magdelena FR (Class I), Mt Magdalena FR (Ext), Part of Gn. Rara Wildlife Corridor FR (Class I), Part of Maliau Buffer Zone FR (Ext) Class I, Batu Timbang FR (Class VI), Imbok FR (Class VI) and Gn. Rara FR (Class I) (Fig. 1). The Kalabakan District Forestry Office administers the reserve. Eleven (11) 0.125 ha plots (20 m radius circular plot) were established end of 2014 and early 2015, and further re-census in 19th till 24th March 2018. In the second census, all previously labelled-trees ≥10 cm diameter at breast height (dbh) within the circular plot and new trees recruited were measured and their species identity were confirmed. Newly recruited trees of ≥10 cm diameter at breast height (dbh) were labelled, re-measured and identify to species level. To investigate changes of trees ≥ 10 cm dbh, the indicators such as plot similarities in species assemblages, mortality and recruitment rates, growth and above ground biomass were evaluated. The findings indicate that forest species assemblages are related to level of past disturbances and edaphic factors. High disturbance areas are grown with secondary tree species, whereas low disturbance are overgrown with advance regenerating lowland mixed dipterocarp forest. In the three-year interval (2015-2018), the species assemblages grouping has shown no deviation from initial observation. The forests demonstrated positive overall tree growths, favourable recruitment rate of diverse species and positive change of above ground biomass. However, the monitoring is too short (monitor period of 3 years only in relative to the longevity of tropical trees) to rationalize these observations. The forests are of various regenerative and successional stages that were previously disturbed by timber extraction activities and should be continuously monitored.

1. INTRODUCTION

This report presents the findings of forest change from 2015 to 2018 in Northern Gunung Rara Sustainable Forest Management Project Area, Sabah, Malaysia (Figure 1). The project area is about 69,777.36 ha and consist of seven forest reserves, i.e. Mt Magdelena FR (Class I), Mt Magdalena FR (Ext), Part of Gn. Rara Wildlife Corridor FR (Class I), Part of Maliau Buffer Zone FR (Ext) Class I, Batu Timbang FR (Class VI), Imbok FR (Class VI) and Gn. Rara FR (Class I) (Fig. 1). The Kalabakan District Forestry Office administers the reserve.

Eleven (11) 0.125 ha permanent sample plots (PSPs) were established end of 2014 and early 2015 (the report refer as 2015), and further re-census in 19th till 24th March 2018.

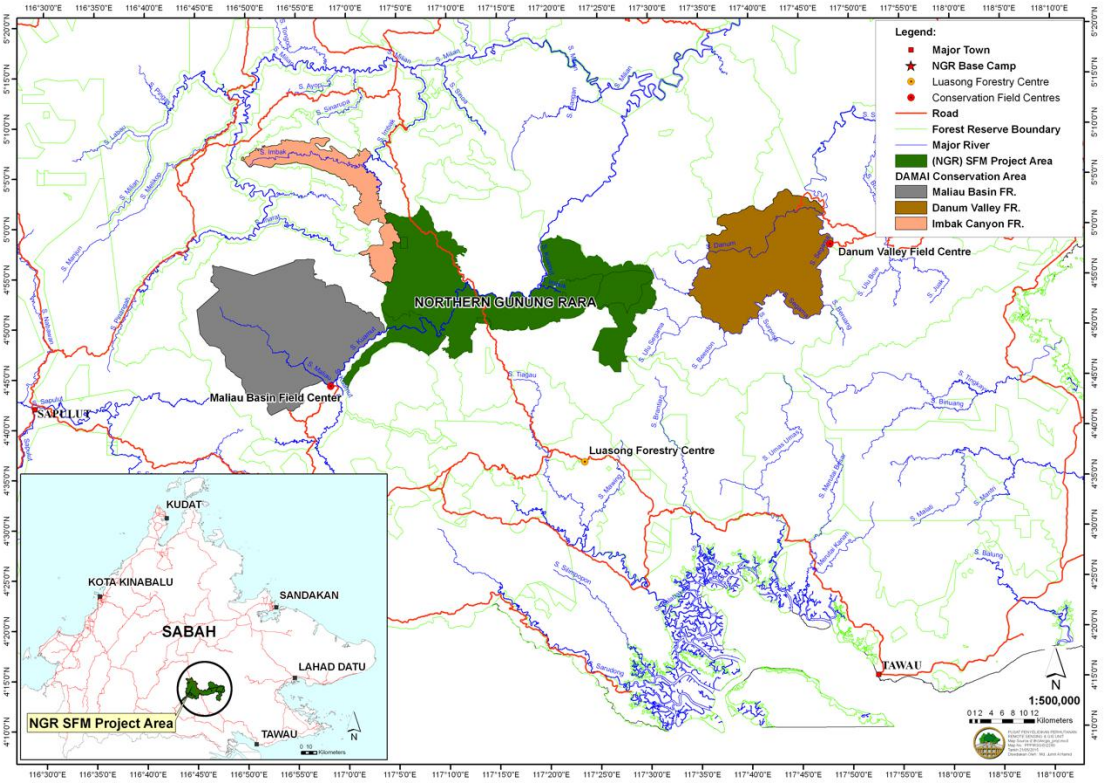


Fig. 1. Location map of Northern Gunung Rara Sustainable Forest Management Project Area in Sabah, Malaysia.

2. OBJECTIVES

The overall objectives of the monitoring activities are to investigate changes of trees ≥ 10 cm dbh according to the prescribe indicators:

i. plot similarities in species assemblages
ii. mortality and recruitment rates
iii. growth
iv. species change
v. above ground biomass

3. METHODOLOGY

3.1 Re-measurement of recorded trees

The location of eleven PSPs is shown in Table 1 and Figure 2. All previously labelled-trees ≥10 cm diameter at breast height (dbh) within 20 m radius circular plot and newly recruited trees were labelled, measured and identify to species level.

Table 1. Summary of location, date of census and altitude of the eleven PSPs at Northern Gunung Rara Sustainable Forest Management Project Area in Sabah, Malaysia.

Plot No.	Location	Ist Census	2nd Census	Latitude	Longitude	Altitude (m)
1	Mt Magdelena	24-Oct-14	19-Mar-18	N 04º 58' 26.0"	E 117º 08' 56.6"	197
2	Mt Magdelena	24-Oct-14	19-Mar-18	N 04º 58' 22.6"	E 117º 09' 0.7"	190
3	Mt Magdelena	13-Nov-15	20-Mar-18	N 04º 58' 47.3"	E 117º 08' 57.2"	190
4	Mt Magdelena	13-Nov-15	20-Mar-18	N 04º 59' 33.4"	E 117º 08' 07.8"	223
5	Mt Magdelena	19-Nov-15	22-Mar-18	N 04º 53' 41.7"	E 117º 23' 45.7"	307
6	Mt Magdelena	19-Nov-15	22-Mar-18	N 04º 53' 55.7"	E 117º 23' 11.7"	283
7	Mt Magdelena	20-Nov-15	22-Mar-18	N 04º 50' 30.5"	E 117º 13' 54.8"	188
8	Mt Magdelena	22-Jan-15	23-Mar-18	N 04º 56' 09.3"	E 117º 10' 34.6"	350
9	Batu Timbang	12-Mar-15	23-Mar-18	N 04º 58' 21.9"	E 117º 05' 57.4"	455
10	Batu Timbang	12-Mar-15	24-Mar-18	N 04º 58' 19.6"	E 117º 05' 51.8"	532
11	Mt Magdelena	13-Mar-15	24-Mar-18	N 04º 55' 43.9"	E 117º 10' 51.4"	267

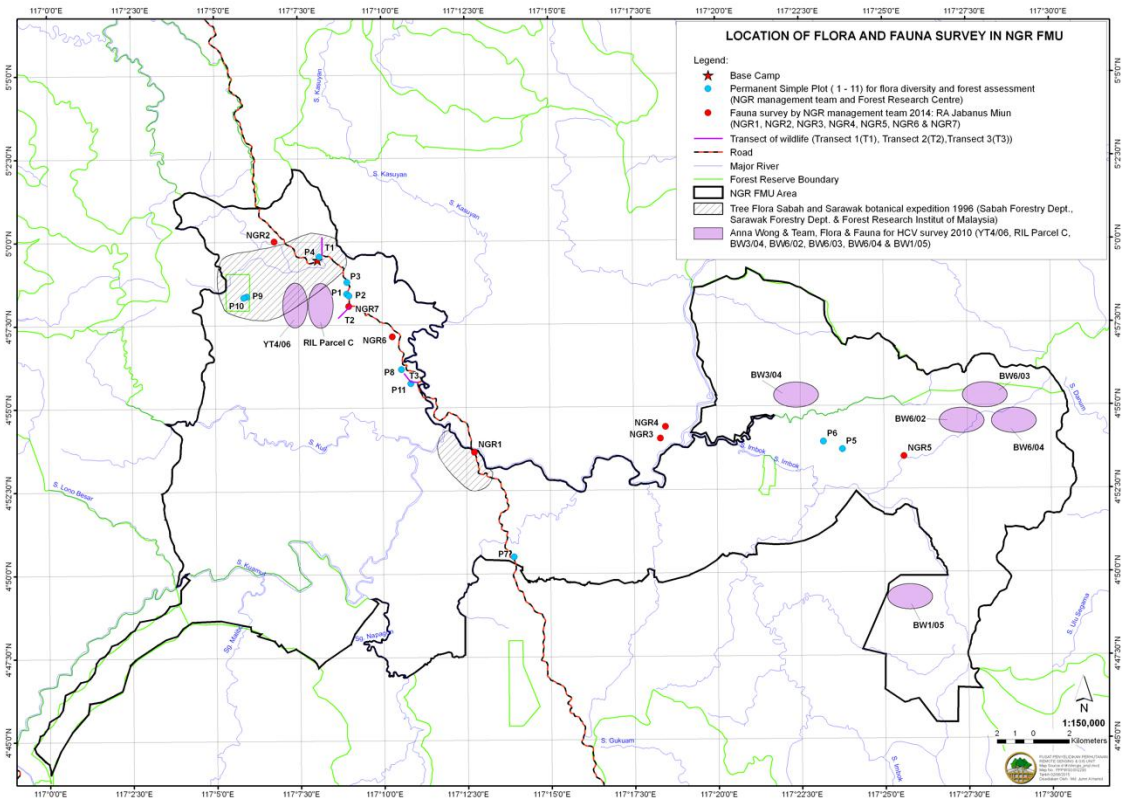


Figure 2. The distribution of the eleven PSPs at Northern Gunung Rara Sustainable Forest Management Project Area in Sabah, Malaysia.

3.2 Data manipulation and analysis

Data analyses were executed for all trees within the 20 m radius to report changes in forest structure and composition. The data set within each sample plot was checked for anomalies such as abrupt changes in an individual's size or irreconcilable changes in species identities (different family or genus). All anomalies were rectified in an attempt to avoid excluding data from the sample.

To investigate species assemblage similarities among plots based on species composition and their abundance, all tree data census in 2015 and 2018 were subject to Bray-Curtis Ordination explicitly (Bray & Curtis, 1957).

Mean annual mortality rates (m) were estimated using the equation provided in Sheil *et al.* (1995):

$$m = 1 - (N_1 / N_0)^{1/t}$$

where N_0 is number of trees at the beginning of a census interval and N_1 is the number of trees surviving at the end of the census interval t (years).

Mean annual recruitment rates (r) were calculated using the equation provided in Sheil (1996):

$$r = 1 - (1 - n_r / N_t)^{1/t}$$

where n_r is the number of recruits and N_t is the number of trees at the end of the census interval t (years).

Turnover rates were estimated as the mean of mortality and recruitment rates.

Annual diameter increment (AGR) and relative growth rate of diameter (RGR) were calculated using the following equations:

$$\text{AGR} = (x_t - x_0) / t$$

$$\text{RGR} = (x_t - x_0 / x_0) / t \times 100\ \%$$

where x_0 and x_t are dbh at the beginning and end of census interval t (years).

Potentially erroneous tree growth data were identified using the criteria adopted by Condit *et al.* (1993b). Trees that shrank by more than 5% of their initial diameter per year or exceeded a mean annual diameter increment of 75 mm year were discarded from the analysis. These minimum and maximum thresholds for growth rates have successfully avoided growth anomalies and provided estimates close to the median of each group of growth data in other studies (Condit *et al.* 1993a). In total, 9 trees were omitted from growth analysis due to erroneous tree growth data.

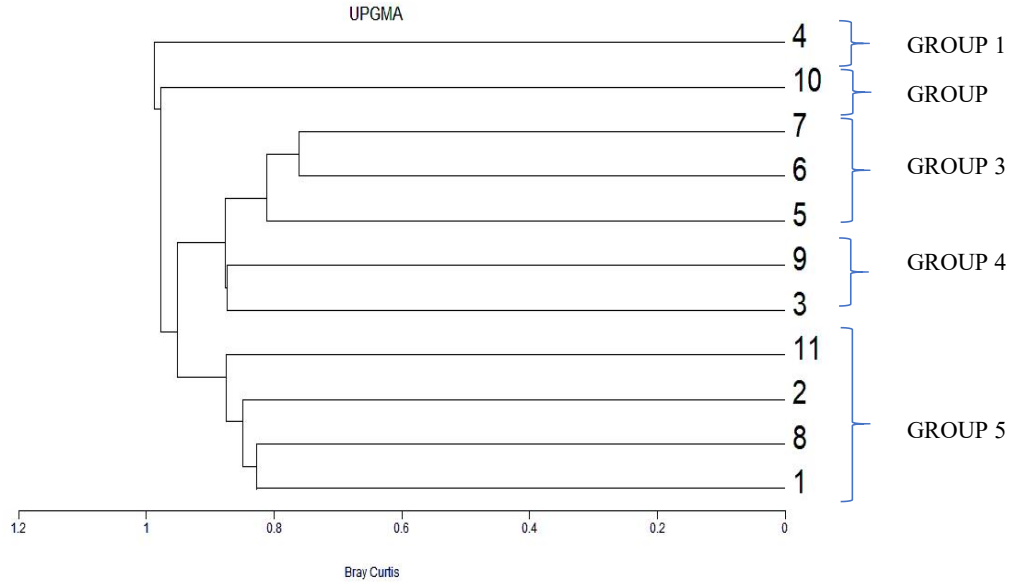
Above ground biomass estimation is computed using EXCEL following the equation "=EXP((-2.134+2.53*(ln(DBH))))" which is based on biomass estimation methods for tropical forests with application to forest inventory data by Brown *et al* (1987).

4. RESULTS

4.1 Plot similarities in relation to species assemblage

The cluster analysis based on species abundance indicated that all PSPs enumerated in 2015 and 2018 can be grouped into five forest types or species assemblages (Figure 3). The grouping can be differentiated in relation to level of past disturbances and edaphic factors. Group 1 and 3 are forest that were dominated by secondary tree species where the former natural climax forest could have been totally cleared in the past. Group 2 is mainly trees that are found associated with limestone substrate. The other groups are mainly advance regenerating lowland mixed dipterocarp forest. In the three-year interval (2015-2018), the species assemblages grouping has shown no deviation from the initial observation in 2015 (Figure 3).

A) Census 2015



B) Census 2018

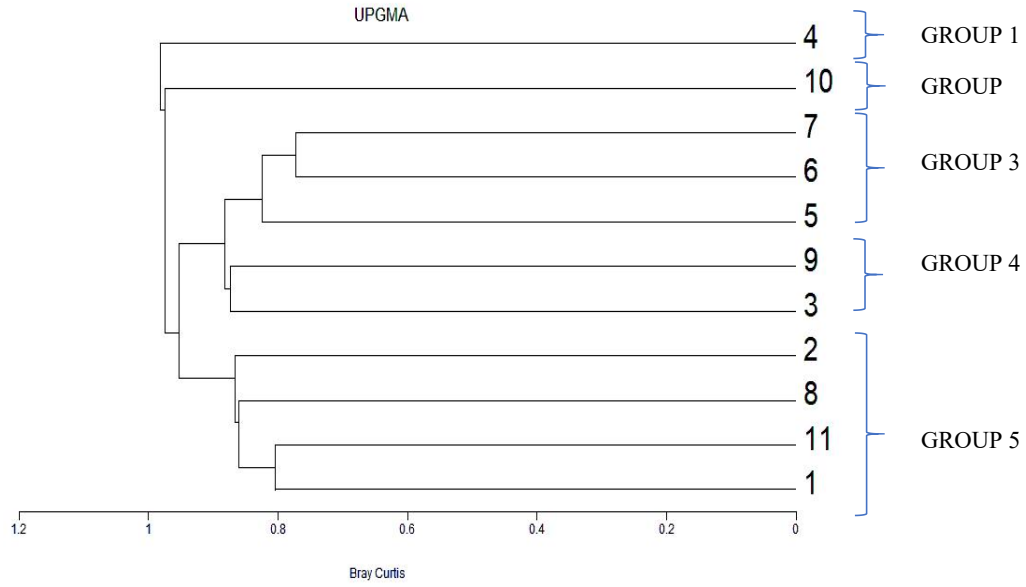


Figure 3. The dendrogram derived from Bray-Curtis ordination analysis (1957) for trees recorded in eleven PSPs at Northern Gunung Rara Sustainable Forest Management Project Area in Sabah, Malaysia: **A)** year 2015 and **B)** year 2018. (Note: 0 = completely similar & 1 = completely dissimilar).

4.1 Comparison of population dynamics for trees ≥10 cm dbh among plots

4.1.1 Mortality, recruitment and turnover

A comparison of tree mortality and recruitment for all sample plots is presented in Table 12. Seven out of eleven plots had greater numbers of recruits than deaths over the interval 2015–2018. Two plots had slightly more mortality than recruitments, and one has similar count of mortality and recruitments. One plot has no observation of mortality and recruitment of trees. In total, tree recruitment is three times more than mortality. The highest number of tree deaths were recorded in Plot 3 and 7, whereas the greatest number of recruits were observed in Plot 1, 4 and 5.

Table 2 Dynamic of trees ≥ 10 cm dbh in all 11 permanent sample plots (PSPs) between 2015–18 in Northern Gunung Rara Sustainable Forest Management project area, Sabah, Malaysia.

Plot No	Tree 2014	Tree 2017	No of Dead	No of Recruit	Mortality Rate (% per year)	Recruitment Rate (% per year)	Turnover Rate (% per year)
1	75	84	3	12	1.19	4.41	2.80
2	69	70	1	2	0.43	0.84	0.64
3	52	56	5	9	2.96	5.08	4.02
4	65	83	0	18		7.01	3.51
5	60	72	2	14	1.01	6.26	3.63
6	34	40	0	6	0.00	4.74	2.37
7	50	48	4	2	2.46	1.26	1.86
8	62	62	7	7	3.71	3.71	3.71
9	57	55	2	0	1.17	0.00	0.58
10	47	47	0	0	0.00	0.00	0.00
11	53	59	1	7	0.63	4.08	2.35
Grand Total	624	676	25	77	1.23	3.40	2.32

4.1.2 Growth

A comparison of tree growth on all sample plots is presented in Table 3. On average, all trees ≥ 10 cm dbh for all plots have demonstrated positive growth within the interval 2015-2018. Trees in Plot 4 demonstrated the highest growth rate and Plot 9 as the lowest.

Table 3 Growth of trees ≥ 10 cm dbh in all 11 permanent sample plots (PSPs) between 2015–18 in Northern Gunung Rara Sustainable Forest Management project area, Sabah, Malaysia. (Annual Growth Rate, AGR; Relative Growth Rate, RGR)

Plot No.	N	Mean of AGR	Min of AGR	Max of AGR	Mean of RGR	Min of RGR	Max of RGR
1	71	0.31 ± 0.06	-0.38	2.55	1.31 ± 0.25	-1.90	9.79
2	67	0.38 ± 0.09	-0.59	4.10	2.11 ± 0.54	-2.70	23.30
3	45	0.44 ± 0.17	-5.06	2.74	2.27 ± 0.47	-4.81	13.68
4	64	0.93 ± 0.09	-0.27	3.93	4.90 ± 0.41	-1.03	17.30
5	57	0.60 ± 0.13	-0.75	4.90	3.99 ± 0.88	-4.98	37.70
6	34	0.74 ± 0.13	-0.36	2.78	2.93 ± 0.49	-2.11	9.67
7	46	0.55 ± 0.10	-1.44	3.20	2.71 ± 0.46	-3.68	16.84
8	55	0.54 ± 0.09	-0.85	3.19	3.28 ± 0.62	-4.48	24.51
9	54	0.23 ± 0.11	-2.24	3.95	0.91 ± 0.22	-3.35	5.90
10	47	0.49 ± 0.10	-0.03	3.59	2.28 ± 0.43	-0.21	17.10
11	50	0.51 ± 0.11	-0.33	4.29	2.63 ± 0.56	-1.82	18.64
Grand Total	590	0.51 ± 0.03	-5.06	4.90	2.66 ± 0.16	-4.98	37.70

4.1.3 Species compositional changes

The number of species that were recruited is almost three times more than those recorded as dead in 2018, i.e. 52 species recorded as newly recruits and 19 species as dead (Table 4). This demonstrated that diverse tree species were recruited in all forest ecosystem throughout the three-year period. The composition of recruited trees also varies between successional group of trees from mixed climax and pioneer species, and also mixed structural canopy, such as main canopy, middle storey and understorey species. Based on plant traits, of the 52 species recruited, about 42% of the list are large stature climax species and 21% as pioneer. As for dead individuals, of the 19 species, both pioneer and climax contributed about 37% of total mortality, respectively.

Table 4 List of species recruited and dead of trees ≥ 10 cm dbh within the eleven PSPs between 2015–18 in Northern Gunung Rara Sustainable Forest Management project area, Sabah, Malaysia.

Plot No	Recruits	Dead
1	*Alangium javanicum* *Ardisia macrophylla* *Artocarpus kemando* *Artocarpus lanceifolius* *Gluta wallichii* *Lithocarpus beccarianus* *Lithocarpus canfleyanus* *Macaranga gigantea* *Shorea ferruginea* *Shorea parvifolia* *Vatica albiramis*	*Nephelium maingayi* *Shorea angustifolia* *Xanthophyllum vitellinum*
2	*Hopea beccariana* *Vatica chartacea*	*Lophopetalum subovatum*
3	*Baccaurea tetrandra* *Cephalomappa malloticarpa* *Dendrocnide eliptica* *Knema latifolia* *Macaranga hypoleuca* *Mallotus molissimus* *Palaquium calophyllum* *Shorea macrophylla*	*Macaranga hypoleuca* *Macaranga indistincta* *Shorea ferruginea*
4	*Litsea garcia* *Ludekia borneensis* *Macaranga cf. grandibracteota* *Macaranga pearsonii* *Nauclea subdita* *Neonauclea artocarpoides* *Norrisia major* *Terminalia citrina*	
5	*Aglaia rufinervis* *Baccaurea macrocarpa* *Brownlowia peltata* *Dendrocnide elliptica* *Garcinia gaudichaudi* *Ludekia borneensis* *Mallotus korthalsii* *Paranephelium joannes* *Parashorea tomentella* *Polyalthia rumphii* *Shorea johorensis* *Syzygium tawahense*	*Macaranga pearsonii*
6	*Callicarpa pentandra* *Dendrocnide elliptica* *Parashorea tomentella* *Symplocos fasciculata*	
7	*Hopea ferruginea* *Sindora irpicina*	*Baccaurea bracteata* *Bridelia sp.* *Callicarpa plumosa* *Litsea acceden*
8	*Aporosa acuminatissima* *Artocarpus lanceifolius* *Chisocheton medusae* *Dacryodes rostrata* *Pentace laxiflora*	
9	-	*Diospyros sp.* *Dryobalanops lanceolata*
10	-	-

11	*Dacryodes laxa* *Dacryodes rugosa* *Shorea macroptera* *Shorea parvifolia* *Shorea pilosa* *Swintonia acuta* *Vatica albiramis*	*Macaranga hypoleuca*

4.1.4 Above ground biomass changes

Throughout the period 2015–2018, the overall total AGB indicates an increase of 8 % from the initial observation value (Table 5). About nine PSPs demonstrated an increase of AGB with range from 6-33% from their initial values, and two PSPs indicated a decrease of 2-13%.

Table 5 Comparison of two census years (2014 and 201)7 on above ground biomass (AGB) per hectare of lived standing trees with ≥ 10 cm dbh within the 11 PSP in Timimbang Botition Sustainable Forest Management project area, Sabah, Malaysia.

Plot No	AGB 2015		AGB 2018		Rate of change %
	N	Total (Mg/ha)	N	Total (Mg/ha)	
1	75	542	84	578	7
2	69	782	70	892	14
3	52	585	56	509	-13
4	65	272	83	362	33
5	60	488	71	478	-2
6	34	171	40	223	31
7	50	283	48	317	12
8	62	185	62	196	6
9	57	792	55	865	9
10	47	315	47	367	16
11	53	356	59	387	9
Grand Total	624	4769	675	5174	8

5. DISCUSSION

5.1 Limitation of findings

In this report, data on above ground biomass, tree growth, mortality and recruitment rates have been obtained from two censuses at 3 years' interval only. Therefore, interpretation of the results should be approached with caution, and further assessments are needed to validate this monitoring observation.

5.2 Changes in forest dynamics and growth over time

Regeneration of residual stand forest in the project area after human induced disturbance are influenced by the level of degradation of the site, availability of regenerative seedlings or saplings, and undergrowth competition such as herbaceous climbers and sedges. Furthermore, the loss of large trees that were extracted during logging activities in the past creates canopy gaps that stimulate the growth of many neighbouring species of various sizes, e.g. understorey seedlings, saplings and pole size trees (Phillips *et al.* 1994). Thus the findings of high recruitment over mortality rate, positive tree growth and incremental trend of above ground biomass may indicate that the natural forests of the project area are recuperating, hence demonstrating that the forests are on successional trajectory towards diverse composition and structural forests.

6. MANAGEMENT RECOMMENDATION

6.1 Protection of forest

Produce a stand-based mapping of vegetation types and the extent of their qualities as baseline reference by using remote sensing technique. The GIS application can be effective management and monitoring tools to examine and evaluate spatial-temporal processes of changes in forest quality and conditions.

6.2 Maintenance of PSPs

Permanent plots require ongoing maintenance and when left unattended for long periods of time, they become increasingly difficult to relocate, re-establish, and to undertake accurate remeasurements. The maintenance of permanent plots consists of determining the presence of center post and tree labels, including inspection of damage to the trees in the plots, and investigate its cause.

7. SYNTHESIS

The forest within the project area has three distinct types. These three forest types of various regenerative and successional stages that were previously disturbed by timber extraction activities are being monitored and found the species assemblages did not deviate from the initial observation. The advance growth forests are recuperating from previous disturbance as demonstrated in the three-year (2015-2018) monitoring programme. The forests demonstrated positive overall tree growths, favourable recruitment rate of diverse species and positive change of above ground biomass. Further monitoring is required.

8. REFERENCES

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