Report on Forest Dynamics Research in Taninthayi Nature Reserve (TNR) Area

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Acknowledgement

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1. Introduction

Taninthayi Nature Reserve (TNR) is located in Taninthayi Region in southern Myanmar and has been notified as a Nature Reserve under the Protected Area System since 2005. It comprises two forest reserves namely Heinze-Kaleinaung Reserve Forest and Luwaing Reserve Forest in the extent of 85,725 ha and 84,273 ha respectively. As a large nature reserve, TNR in its total area of 169,998 ha lies in the Ecoregion of Tenasserim-South Thailand Semi-Evergreen Rain Forests according to WWF-2002 Terrestrial Ecoregions of the Indo-pacific (Win & Pyone, 2013). TNR area is a part of Taninthayi Range along the border between Thailand and Myanmar, where mountainous, tropical evergreen forests with rich biodiversity have occupied. A large diversity of plants and animals play an important role in ecological sustainability as well as local livelihoods of this area.

For conservation of tropical rainforests and biodiversity in Taninthayi Nature Reserve area through the participation and sustainable livelihoods of local communities, Taninthayi Nature Reserve Project (TNRP) has been implementing under the collaboration between Ministry of Natural Resources and Environmental Conservation, Forest Department and three international corporations namely Moattama Gas Transportation Company Limited (MGTC), Taninthayi Pipeline Company (TPC) and Andaman Transportation Limited (ATL). From the first phase of TNRP (2005–2009) to the third phase (2013–2017), several researches for flora and fauna, medicinal plants, non-timber forest products and community forests were conducted either in a regular term or in research needs of the project management.

During the second phase (2009–2013) of the project, TNRP assigned a national consultant for forest dynamics research to analyze floral distribution, plant diversity and forest structure of TNR area. To update baseline data on richness and distribution of flora of the nature reserve, forest dynamics research in TNR area was again conducted in 2019 in order to support the implementation of fourth phase management plan (2017–21) of TNRP. Therefore, with the aim of understanding floristic composition and forest structure of TNR to promote conservation, maintenance and sustainability of biological diversity as well as to support the baseline information in implementation of biodiversity database and management plan of TNRP, this research on forest dynamics was carried out during September to December, 2019 in the project area.

2. Methodology

Study area is mainly composed of undulating mountain range, running from North to South, with well drained hill slopes. For the project implementation, TNR area is managed by each of ten administrative units (Local Operating Units-LOUs) in its wide range of topography and also divided into buffer zone, core zone and transportation corridor mainly for service track of gas pipelines (Pollard et al., 2014). The area of TNR is predominantly covered with forests, consisting of evergreen forests at higher elevations, semi-evergreen forests at lower elevations in the west and degraded secondary forests closer to the human residence areas in the west of the reserve. Local people are mainly Dawei, Mon and Karen ethnic groups who live on home gardening, hill cultivation, forest-related resource extraction such as non-timber forest products collection and hunting, and laborer in and around Myanmar-Thailand border area. Since peace groups of Karen and Mon are active in some parts of the reserve forest, TNRP has been implementing conservation activities through engagement with peace groups at some places where accessibility is restricted.

Consultancy report on forest dynamics research of TNR at the second phase of the project (Aung, 2012) and consultancy report on flora survey in TNR (Thein, 2007) were reviewed to develop sampling design based on the previous studies. Aung (2012) recorded floristic composition and forest structure in three sample plots which were permanently set up in (i) Mayan Chaung (8-6 point on the service track), (ii) Yebon and (iii) Kyaut Shut LOUs. Field survey of that study was conducted in each quadrat of 50 m x 100 m, covering 1.5 ha of sample size in three permanent plots totally. Re-enumeration of number tagged trees was conducted in two successive years and changes in stand structure were reported as forest dynamics occurred within the research period (2010–2012) (Aung, 2012). In the study on floristic composition of TNR area, Thein (2007) found that floristic types and habitats were different among five sample plots. The study suggested that minimum sample size of 1.3 ha was adequate in each of the two sample plots, however, that of 1.4 ha in the other plots could be extendable to achieve representative sampling area for flora survey in TNR and total sample area of 6.6 ha was quite adequate overall.

Situations of the permanent sample plots of forest dynamics research (2010-12) were enquired from the Park Warden office of the project and LOUs concerned. Sample plot in Mayan Chaung (8-6 point of the service track) was extremely disturbed by illicit logging and consecutive forest fires within the last three years due to unavoidable security issues in the project area when the other two plots remain almost undisturbed by anthropogenic factors except a few natural disturbances such as seasonal fires and storms.

2.1. Study site

With reference to the preliminary field observation of permanent sample plots and review of the previous reports on flora survey and forest dynamics research, Heinze, Thetke Kwet and Kalone Htar LOUs were selected to set up a new permanent plot of 50 m x 100 m (0.5 ha) in each LOU. Including the existing permanent plots, sample plots were allocated in core zone of TNR by subjective sampling to ensure that the plots were located at least 5 km distance between each other and along the north-south range of TNR area, and also with consideration of further management and monitoring of permanent sample plots by LOU staff (Fig.1). Therefore, this study explored floristic composition and forest structure in totally six sample plots including three existing permanent plots and three newly set-up plots, in total area of 3 ha, and analyzed compositional and structural dynamics of forests in three existing sample plots which were previously studied during 2010-12.

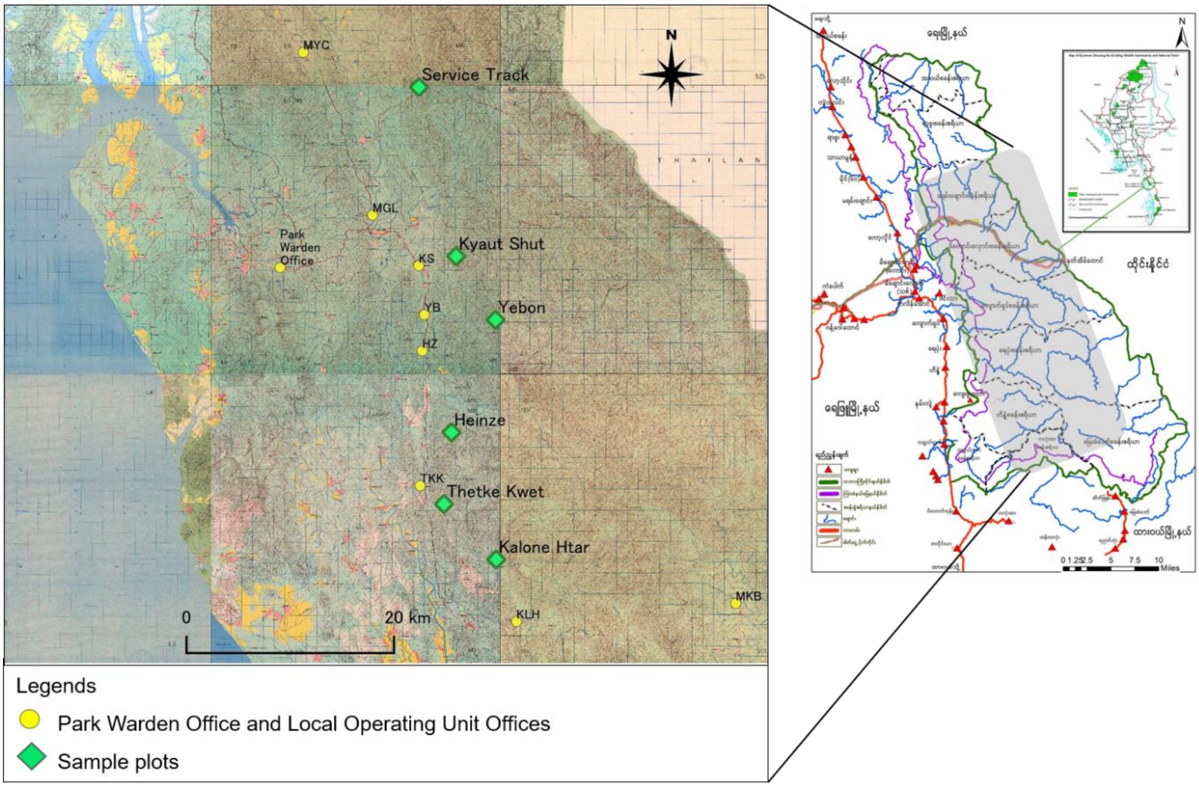


Fig. (1) Location of sample plots for forest dynamics research in Taninthayi Nature Reserve

2.2. Data collection

Following the methods in forest dynamics research (2010-12), threshold of tree was determined at 3.2 cm of diameter at breast height (dbh) (cm at 1.3 m above ground) to record species and to measure dbh and top height (h) in newly set up plots. Every stem at and above the threshold was number-tagged by using steel number plate which was attached to the tree for measurements in future surveys. In the existing permanent plots, the same measurement was done for the number-tagged and living trees, and additionally, current status such as damage to tree was recorded. During the field survey, some trees and branches with dbh less than the threshold were found number-tagged and those as recorded trees of the previous work on forest dynamics research were also included in the measurement of this study. Dead trees were also counted by determining threshold validity for stems without number tag and by taking numbers for stems with the number tags whenever available. Species occurred and abundance of tree regeneration (plant height<1.3 m) were counted in subplots of 20m x 20m in four corners of each sample plot in total area of 0.16 ha for each plot (Fig.2).

Setting of new sample plots, demarcation of the existing plots and enumeration and measurement of trees were carried out through the participation of LOU staff who were informed data collection methods at the field survey orientation.

Tree species commonly found in the study area were recorded by local name with the help of field identification team led by local people who were experienced in timber extraction and forestry operations in TNR area. Photos were taken for some species which were difficult to be identified in the field, then, those were identified with reference to the tree checklist (Kress & Lace, 2003), standard nomenclature of forest plants of Myanmar (Lin, 2016), International Plant Names Index (IPNI) of the Royal Botanic Gardens, Kew, and the consultancy report on forest dynamics research (2010-12). Global Positioning System (GPS) points of sample plots were marked for future demarcation. Sunto clinometer, handy compass and 50-m measure tape for ground survey, 8-m diameter tape for tree dbh, 5-m measuring pole and Nikon Laser Range Finder for tree height, and Garmin GPS Maps 62st were used for setting up plots and the tree measurements.

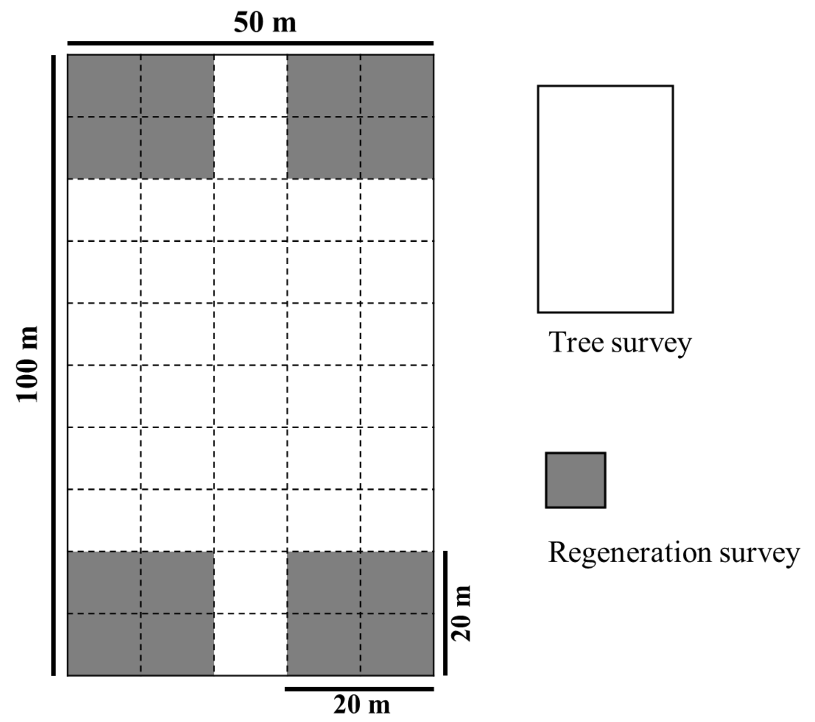


Fig. (2) Sample plot design for field data collection in forest dynamics research

2.3. Data analysis

Floristic composition was explored by measures of total species richness, species-area curve, tree diversity and evenness indices, and importance value index (IVI) using the following formulae.

Richness S = number of species observed in unit area

Shannon-Weiner index $H' = -\sum_{i=1}^{s} \frac{n}{N} \log\left(\frac{n}{N}\right)$

Simpson index $D = 1 - \frac{\sum_{i=1}^{s} n(n-1)}{N(N-1)}$

Evenness $E = \frac{H'}{Log\ (N)}$

Where, s = number of species in a sample plot

n = number of trees for individual species

N = total number of trees in a sample plot

Importance value index IVI = Relative density + Relative frequency + Relative abundance

Where, Density = Number of a species/ Total area sampled

Frequency = Area of plots in which a species occurs/ Total area sampled

Abundance = Total basal area of a species/ Total area sampled

Hierarchical cluster analysis was applied in grouping the sample plots based on their composition of species (present-absent) to explore similarity in species composition among the six sample plots. To analyze representativeness of the sampling area in relation with the species richness, species-area analysis was carried out.

Stem density, basal area, relative dominance (basal area of common species), and stem distribution in diameter and height classes were calculated for stand structure description of forests in the six sample plots. Compositional and structural dynamics of forests in three sample plots of forest dynamics research (2010-12) comparing with the current study was examined by analyzing species composition, stand structure and annual mortality rate for the period from 2012 to 2019. Regeneration abundance was examined to help understanding compositional dynamics of the studied forests. As the availability of raw data of previous survey was limited and some of the tree number tags in the permanent sample plots were damaged or lost, comparisons of stem density per hectare, relative dominance by common species, and stem distribution in tree size classes were analyzed for overall structural dynamics whereas growth rate of individual stems could not be calculated.

Descriptive and ecological analyses were carried out by using Microsoft Office Excel 2016, IBM SPSS v.22 and PC-ORD v.7.04 for windows (Ennos, 2007; McCune et al., 2002; Peck, 2016).

3. Results

3.1. Species composition

Total number of species observed in this study was 157 and that observed in each of the sample plots was 77 in 30 families at Thetke Kwet-TKK, 57 in 27 families at Heinze-HZ, 55 in 29 families at Service Track-ST, 43 in 22 families at Yebon-YB, 43 in 23 families at Kyaut Shut-KS, and 34 in 22 families at Kalone Htar-KLH respectively (Table 1). Species diversity indices showed the highest diversity at TKK followed by HZ and ST, and slightly lower diversity values at YB, KS and KLH (Table 1). Evenness of species abundance over the sample area was also found higher at TKK, HZ and ST than at the other plots (Table 1).

Hierarchical cluster analysis explored grouping of the sample plots with similar species composition and showed that composition of species in six plots were different into five groups at the cut-off line with 67.5 % of retained information (Fig. 3). Species composition in KS and YB was similar whereas that differs within the other plots. The results show that floristic composition of TNR area is heterogenous with a large diversity in geographical features at different sites, elevations and microclimate characteristic to the wide range of nature reserve.

Table (1) Tree species richness, diversity and evenness in each sample plot

Sample Plot	Richness (S)	Shannon's Diversity Index (H′)	Simpson's Diversity Index (D)	Evenness (E)
Thetke Kwet (TKK)	77	3.48	0.95	0.80
Heinze (HZ)	57	3.33	0.95	0.82
Service Track (ST)	55	3.24	0.93	0.81
Yebon (YB)	43	2.71	0.89	0.72
Kyaut Shut (KS)	43	2.86	0.92	0.76
Kalone Htar (KLH)	34	2.25	0.82	0.64
Averages	51.5	2.98	0.91	0.76

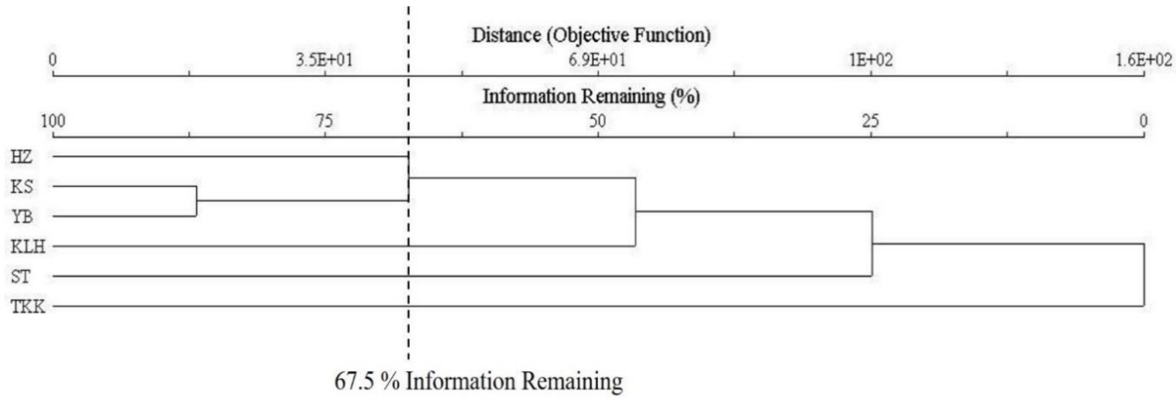


Fig. (3) Hierarchical clustered diagram of the sample plots with information on their species composition by using present-absent data of individual species (Hierarchical cluster analysis was done by Euclidean distance measure and Ward’s linkage method in PC-ORD v.7.04)

Species-area relation of the six sample plots was examined and resulted in extendibility of sample area to represent species richness of the whole study area (Fig. 4). As the tree species composition varies among different sites within the large TNR area and species diversity of tropical forests is usually high, this study indicates that total number or size of the sample plots need to be increased to estimate representative richness of tree species in researches which will be carried out for monitoring floristic composition rather than growth performance of specific permanent plots in the large project area.

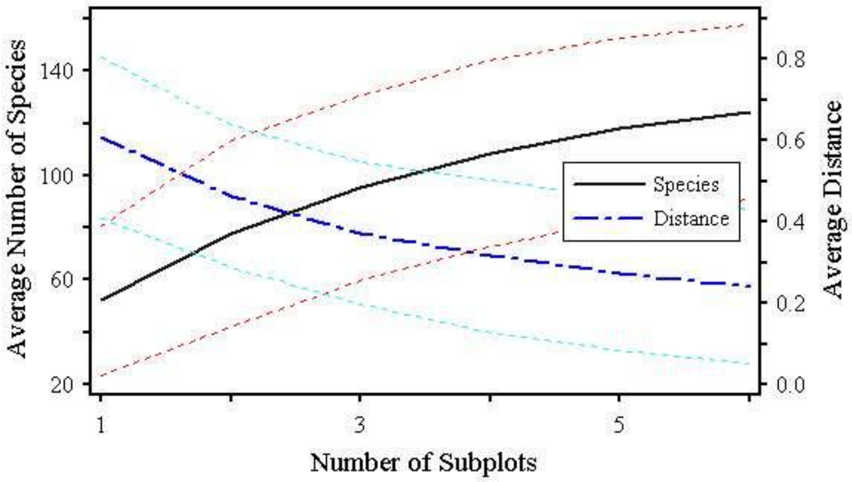


Fig. (4) Species-area curve of the six sample plots in the area of 0.5 ha for each and total sampled area of 3.0 ha.

Table (2) presented the rank of tree species with importance value index which was resulted from the sum of density, frequency and abundance relative to the total sample. Therefore, this value represents how a species is dominant in a given area. Composing one-third of the ranking value (about 130 out of 300), 19 species with IVI≥4.0 were reported for dominant species in this study (Table 2). The most dominant species was *Swintonia floribunda* (taung-thayet) and top-ranking dominant species mostly belong to families Anacardiaceae, Meliaceae, Myrtaceae and Sapindaceae, including abundant and large-sized trees such as kyet-mauk, tha-bye, gat-thit-to, gat-pok, etc.

Table (2) Dominant species in ranking with Importance Value Index-IVI (sum of relative density, relative frequency and relative dominance) of tree species in the total sample area

Sr. no.	**Botanical name**	**Family**	**IVI**
1	*Swintonia floribunda* Griff.	Anacardiaceae	21.44
2	*Eugenia* sp. (1)	Myrtaceae	15.32
3	*Aporosa* sp.	Phyllanthaceae	13.69
4	*Aphanamixis polystachya* (Wall.) R.Parker	Meliaceae	12.91

Sr. no.	Botanical name	Family	IVI
5	*Nephelium* sp.	Sapindaceae	10.57
6	*Nephelium* sp. (2)	Sapindaceae	8.52
7	*Litsea* sp.	Lauraceae	7.93
8	*Diospyros malabarica* (Desr.) Kostel.	Ebenaceae	7.23
9	*Dillenia parviflora* Griff.	Dilleniaceae	7.11
10	*Ficus semicordata* Buch.-Ham. ex Sm.	Moraceae	7.08
11	*Aglaia lawii* (Wight) C.J.Saldanha	Meliaceae	6.14
12	*Knema angustifolia* (Roxb.) Warb.	Myristicaceae	5.95
13	*Diospyros brandisiana* Kurz	Ebenaceae	5.67
14	*Pentace griffithii* King	Malvaceae	4.76
15	*Aglaia spectabilis* (Miq.) S.S.Jain & S.Bennet	Meliaceae	4.61
16	*Callerya atropurpurea* (Wall.) Schot	Fabaceae	4.46
17	*Barringtonia angusta* Kurz	Lecythidaceae	4.41
18	*Castanopsis* sp.	Fagaceae	4.08
19	*Gluta* sp.	Anacardiaceae	4.06

3.2. Stand structure

The number of stems per hectare were recorded the highest at 2090 for KLH, followed by YB with 1744, TKK with 1726, KS with 1720, HZ with 1122, and ST with 622. However, the largest basal area per hectare of trees were counted for TKK and KS followed by YB, HZ and KLH, and the least for ST (Fig. 5), showing that small trees in a large number of stems were commonly found at KLH and YB. Consequently, the largest number of small trees (dbh 2.0–20.0 cm) at KLH compared with the other sites was resulted as shown in Fig. (6). Distribution pattern of dbh classes, the largest number in small trees and the least in large trees (dbh≥30.1 cm), was similarly found at all sites (Fig. 6). Large-sized trees were more abundant in TKK, KS, YB and HZ, where species diversity and basal area were also relatively high, than KLH and ST. Similarly, in the stem distribution in height classes, medium and high trees (h 20.1–45.0 m) were rarely found in KLH and ST plots (Fig. 7). Stem distribution in different height classes also showed the reverse-J shape for the distribution pattern of larger number of trees in low height classes than the number in higher ones.

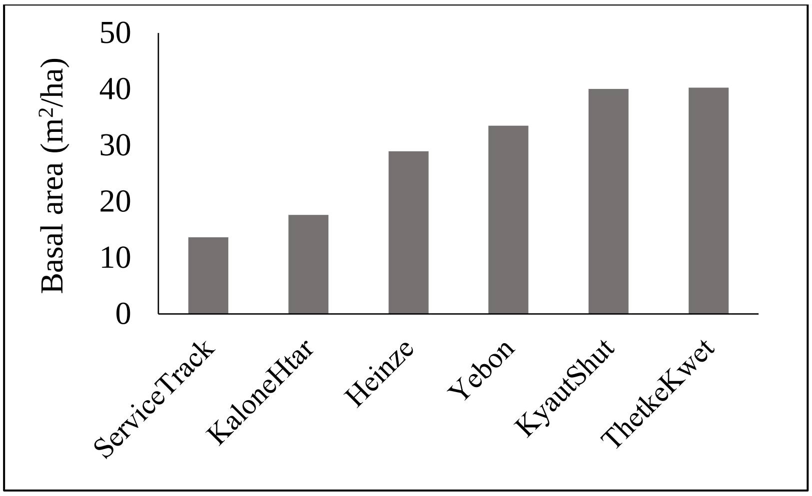


Fig. (5) Tree basal area at six study sites

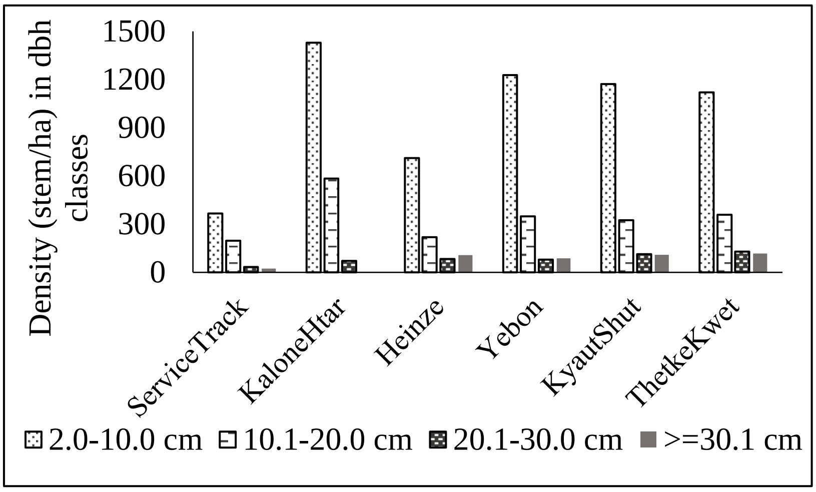


Fig. (6) Stem distribution in tree diameter classes at six study sites

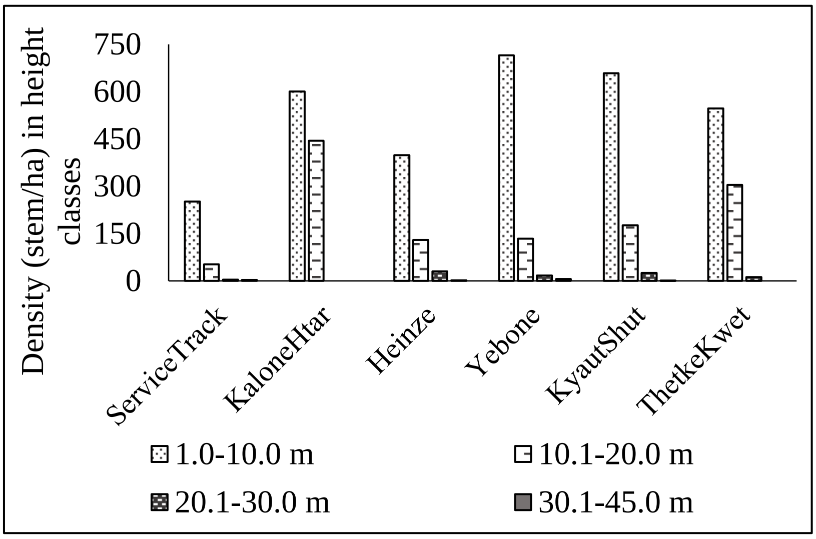
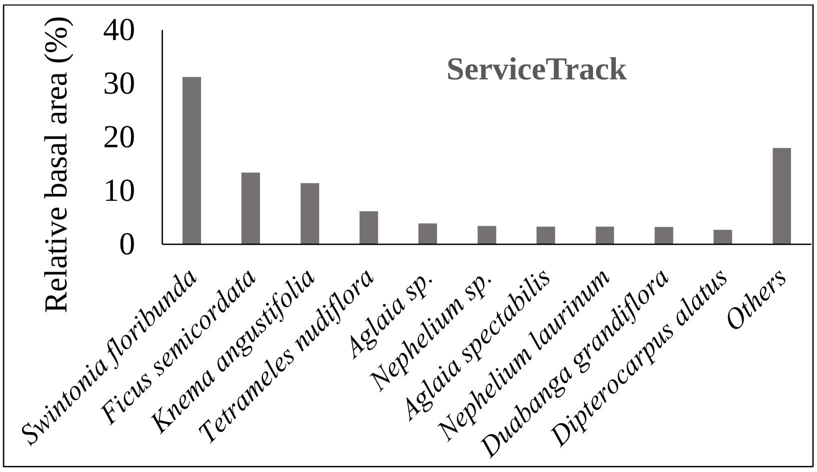
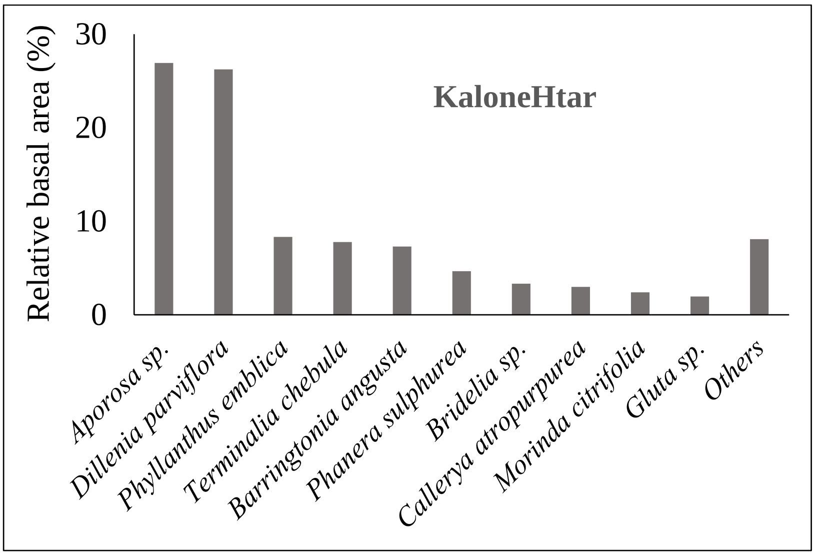


Fig. (7) Stem distribution in tree height classes at six study sites

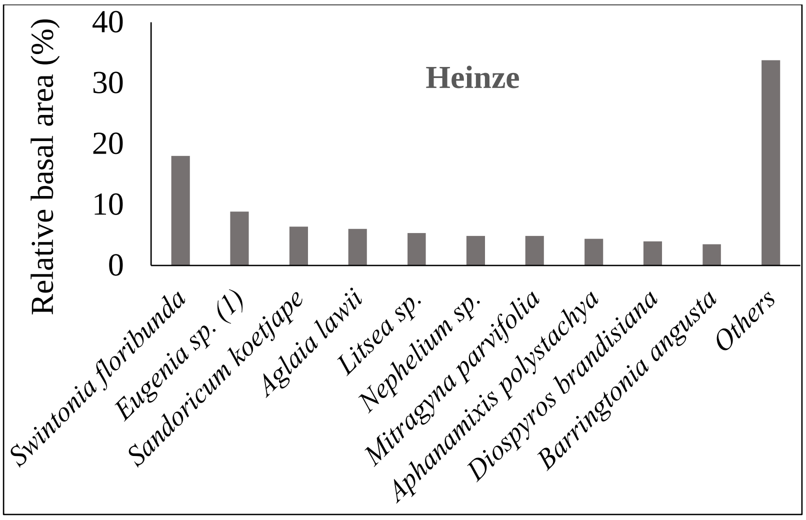
Dominant tree species in terms of relative basal area at each study site were described in Fig. 8 (a–f). Dominant species such as *Swintonia floribunda*, *Nephelium* sp., *Eugenia* sp., *Ficus semicordata* and *Aphanamixis polystachya* occurred similarly at four or five study sites except KLH. Tree species with a large percentage of dominance at KLH were totally different from those at the other sites (Fig. 8b). Large proportions of dominance were accumulated in top two or three dominant species at ST, KLH, HZ, YB and KS (Fig. 8a–e), however, almost even proportions of dominance were shared in many tree species at TKK (Fig. 8f).



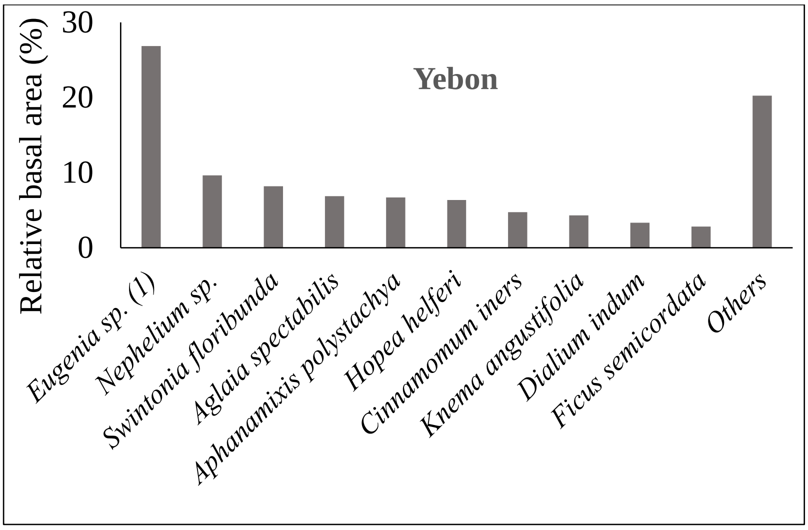
(a)



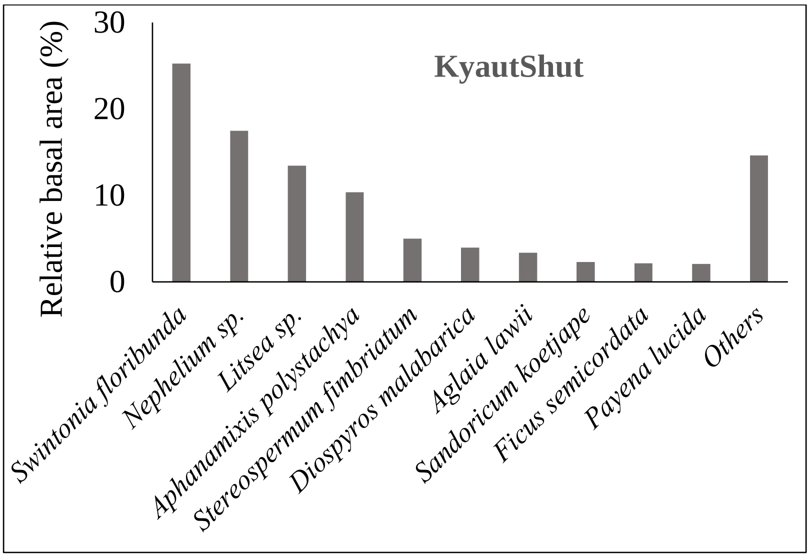
(b)


Heinze
Relative basal area (%)
40
30
20
10
0
Swintonia floribunda
Eugenia sp. (1)
Sandoricum koetjape
Aglaia lawii
Litsea sp.
Nephelium sp.
Mitragyna parvifolia
Aphanamixis polystachya
Diospyros brandisiana
Barringtonia angusta
Others

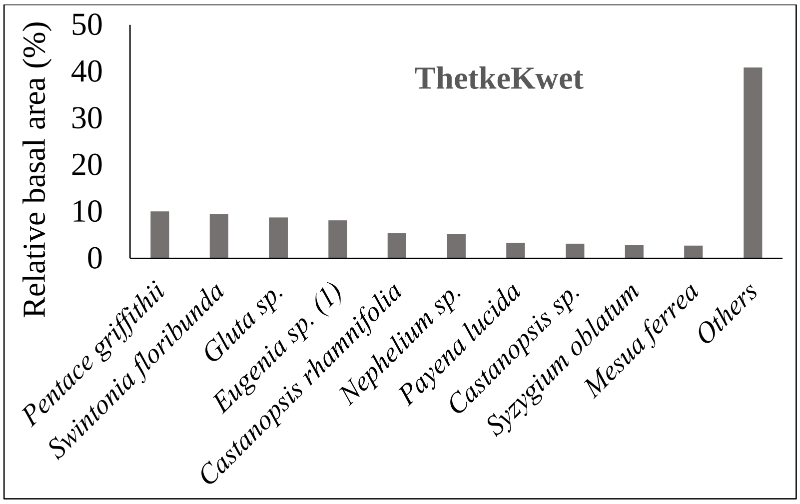
(c)


Yebon
Relative basal area (%)
30
20
10
0
Eugenia sp. (1)
Nephelium sp.
Swintonia floribunda
Aglaia spectabilis
Aphanamixis polystachya
Hopea helferi
Cinnamomum iners
Knema angustifolia
Dialium indum
Ficus semicordata
Others

(d)


KyautShut
Relative basal area (%)
30
20
10
0
Swintonia floribunda
Nephelium sp.
Litsea sp.
Aphanamixis polystachya
Stereospermum fimbriatum
Diospyros malabarica
Aglaia lawii
Sandoricum koetjape
Ficus semicordata
Payena lucida
Others

(e)



(f)

Fig. (8) Relative basal area of the most common species at six study sites (a) Service Track (b) Kalone Htar (c) Heinze (d) Yebon (e) Kyaut Shut and (f) Thetke Kwet

3.3. Regeneration occurrence

Species richness and diversity of tree regeneration were not much different among the study sites (Table 3) where totally observed number of species was 62. However, the smallest number of regeneration species and diversity index were observed at TKK where tree species richness and diversity were the highest and basal area and the number of large-sized trees were larger than the other sites. About 70% of the relative density of tree regeneration were contributed by 9 species (Fig. 9) of which *Shorea* sp. and *Dipterocarpus* sp. were not observed in dominant tree species but dominant in regeneration.

Table (3) Species richness, diversity and evenness of tree regeneration (plant height<1.3 m) in each sample plot

Sample Plot	**Richness (S)**	**Shannon's Diversity Index (H′)**	**Simpson's Diversity Index (D)**	**Evenness (E)**
Kyaut Shut (KS)	22	2.78	0.92	0.90
Service Track (ST)	20	2.87	0.93	0.96
Heinze (HZ)	18	2.43	0.88	0.84
Kalone Htar (KLH)	18	2.63	0.91	0.91
Yebon (YB)	17	2.54	0.91	0.90
Thetke Kwet (TKK)	15	2.24	0.86	0.83
Averages	18.3	2.63	0.90	0.89

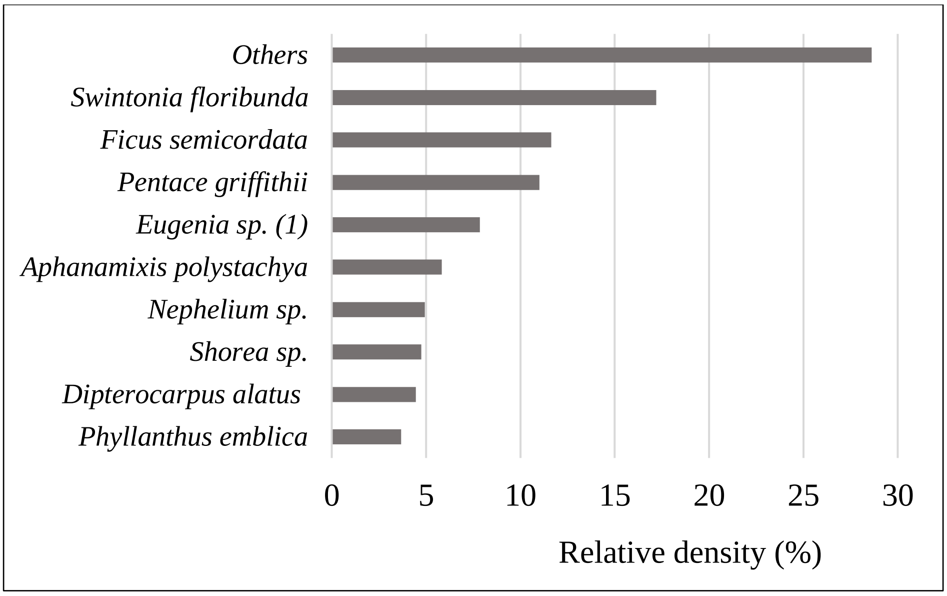


Fig. (9) Relative density of dominant species in tree regeneration in total sample area

3.4. Compositional dynamics

For all three permanent plots at ST, YB and KS, tree species richness and diversity were found lower in this study than in the previous forest dynamics research although evenness was not much different (Table 4). At YB and KS, the numbers of rare species which had only one occurrence in a sample plot were larger in the previous study than in the current study. Similar to the previous study, dominant tree species in the families Meliaceae, Lauraceae and Myrtaceae occurred in this study.

Table (4) Floristic composition comparison of three permanent plots between 2012 and 2019

Year	2012			2019		
	ST	YB	KS	ST	YB	KS
No. of families	32	37	38	29	22	23
Species richness S	100	129	130	55	43	43
Rare species contribution % (f = 1)	27	35	30	29	28	19
Shannon's Diversity Index (H')	5.27	5.56	6.15	3.24	2.71	2.86
Evenness (E)	0.79	0.79	0.88	0.81	0.72	0.76

3.5. Structural dynamics

Total number of stems per hectare decreased overall in each permanent plot and extremely in ST plot which was damaged by logging disturbance and consequent forest fires in recent years (Table 5). Majority of decrease in stem density occurred in small- and medium-sized dbh classes but not in the large size class of trees enumerated. Therefore, no prominent changes in basal area was observed for trees in the permanent sample plots except in an extremely damaged plot at ST. Due to limitation in monitoring tree number tags and acquiring raw data of the previous survey, individual dead trees could not be identified during 7-year period between the two surveys of forest dynamics researches. During field survey of this study, dead trees were counted for the observed dead stems at and above the threshold either with or without number tags which were sometimes lost, damaged or burnt. Observed number of dead stems in this study and recorded number of stems in 2012 were used for calculation of annual mortality rate to estimate structural dynamics for the period 2012-2019. Annual mortality rates (2012-2019) at YB and KS in this study were slightly less than those of the previous survey and the rate at ST was slightly higher probably due to intense logging disturbance.

Table (5) Forest structure comparison of three permanent plots between 2012 and 2019

Year	**2012**			**2019**		
	ST	**YB**	**KS**	**ST**	**YB**	**KS**
No. of stems/ha	1566	1868	1788	622	1744	1720
Small (dbh 2.0–20.0 cm)	1428	1604	1492	564	1576	1496
Medium (dbh 20.1–30.0 cm)	104	176	210	34	80	114
Large (dbh>=30.1 cm)	34	88	86	24	88	110
Basal area/ha	33.56	36.62	37.61	13.63	33.52	40.04
No. of stems/plot	783	934	894	311	872	860
Difference in no. of stems/plot (2012-2019)				472	62	34
No. of dead stems/plot (observed)				140	62	70
Annual mortality rate* (2012-2019)				2.55	0.95	1.12

*Annual mortality rate for the period of 2012-2019 was calculated with reference to the consultancy report on forest dynamics (2010-2012) by using the number of stems per plot in 2012 and that of dead trees which were observed in the current field survey.

4. Discussion

Tree species diversity indices and species-area relation revealed that floristic composition of TNR area is highly diverse and varies at different sites with different geographical features because of its large range of nature reserve area covered with tropical evergreen and semi-evergreen forests. Dominant species in families Anacardiaceae, Meliaceae, Myrtaceae and Sapindaceae elucidate typical forest conditions of TNR characteristic by moist deciduous and evergreen trees (Asouti & Fuller, 2008). Most dominant species occurred at KLH were different from the species dominant at other five plots of this study (Fig. 8a–f) due to variation in geographical features and past history of the sampled forests. Forests at KLH sample plot represented deciduous vegetation in lowland of the mountain range and the sample plot fall in the area where metal mining related activities had occurred about 35 years ago in the past. Inclusion of this plot in addition to typical evergreen forests in the other sample plots might help understanding successional stages of deciduous and semi-evergreen forests in TNR area in future research.

Overall, species richness and diversity of three permanent plots were reported higher in the previous study; however, rare species occurrences were also high. It may be resulted from fast-growing and short-lived species, which usually occurred at early stages and disappeared lately after being occupied by secondary species (Turner, 2001), when conservation works have continuously carried out. Forests in the study area provided good source of timber until the time before notification of nature reserve for conservation forests. Since logged over and secondary forests have been conserved for about 15 years with conservation purpose, succession period is short yet for tropical evergreen forests in this area where floristic composition seems to be gradually changing. Some of the dominant species, such as *Shorea* sp. and *Dipterocarpus* sp., in tree regeneration were also found not being included in dominant species of adult trees.

Stem distribution in tree diameter and height classes presented early successional stages of forests where the largest number of stems contributed into small size classes and the least in the large size class. Therefore, relative dominance (basal area) largely accumulated in two or three dominant species sharing only a few percentages with the remaining. Those results in KLH plot indicated that forest structure is dominant by understory trees in its dynamic population rather than the canopy species.

Comparing stem density of three permanent plots between years 2012 and 2019, the majority of decrease in the number of stems was observed in smaller dbh classes and not in the larger; even increase in the large size class at KS (Table 5). The results explained that natural disturbances such as strong winds, tropical storms and seasonal fires in this area might not seriously defect growth of the canopy species. However, understory tree species seems to be reduced during natural process of forest dynamics at its early successional stages. Besides, damages from a fallen large tree and fires in consequent dry season were observed causing huge defects on surrounding small trees in the field. Therefore, disturbances by either natural or anthropogenic factors are predicted to be serious more on smaller understory trees than the canopy. Except at ST sample plot where illicit logging was uncontrollable due to limitation in secure accessibility and forest governance, anthropogenic disturbances were rarely observed either at the sample plots or within the studied forests. Sample plots are located nearby local conservation forests which are managed for purposes such as water resource supply and community forest. Thus, local people are aware and often participate in maintaining permanent sample plots, especially reporting unusual events if any happens in the studied forests.

Since dead trees could only be recorded at sight in the field instead of re-enumeration using inventory data of the previous survey, species and diameter of those stems could not be counted for detailed analysis of mortality because most of the dead stems were already damaged or burnt down on ground. However, annual mortality rate was estimated from stem density data within the period 2012-2019 and the results showed that the mortality rate remained nearly the same as reported in the previous research on forest dynamics. For a long-term study on dynamics of tropical rain forest, repeated enumeration methods are common to be practiced (Turner, 2001) and continuity and persistence of survey data are so critical that structural changes of the studied forests in a given period can be analyzed.

5. Conclusion and recommendations

This research explored floristic composition and stand structure of forests at three existing permanent sample plots and three newly set-up plots, total area of 3 ha, and analyzed compositional and structural changes of forests in the existing sample plots with reference to the previous report on forest dynamics in TNR area. Compared with main findings in the previous report, overall diversity and richness of tree species decreased and it was supposed to be successional changes in floristic composition of tropical rain forest as the studied forests were previously managed for production and under current protected area conservation status less than 15 years. Characteristic species and dominant species were also found slightly varied with findings in the survey of 2012. Forest stand structure did not expose any distinct changes in diameter class distribution pattern as well as the number of stems in larger size classes as far as the sample plot was not intensely disturbed by anthropogenic factors. Understory trees were likely to be affected by natural disturbances more seriously than the canopy because of damage caused by not only direct disturbance but also large fallen trees in their surroundings. Relatively high density of some regeneration species which are not dominant in adult trees showed a good indicator of forest succession under the present conservation status. In conclusion, current activities of forest conservation incorporating with local community supply and wildlife habitat restoration, e.g. establishment of watershed conservation and community-managed forest, and enrichment planting of wildlife-attractive trees, would be able to facilitate forest succession through its natural dynamics.

For more effective management of conservation forests in TNR area with emphasis on facilitating natural ecological succession through non-conflicting activities with integration of wildlife conservation and local supply, this study suggests the following recommendations in future research and management activities;

(a) Monitoring permanent sample plots and annual data collection should be done by respective LOU so that cumulative and continuous data from repeated enumeration will be available for detailed analyses by the assigned consultant for periodical research on forest dynamics.

(b) Total number or size of the sample plots should be increased to estimate representative richness of tree species if future research will be purposed for monitoring floristic composition of the project area, and consequently, justification of forest dynamics research might be considered for cost, time and effectiveness.

(c) Based on the findings in ongoing researches, successional traits of selective tree species including regeneration should be studied by narrow-down approach for in-depth understanding on forest dynamics.

(d) Research in forest ecology such as interaction of natural regeneration with wildlife and anthropogenic intervention should be promoted simultaneously with forest dynamics research in order to provide scientific conservation guidelines for the nature reserve in line with its management goals.

(e) Dissemination of research findings through proper channels to decision makers and stakeholders as reachable as possible will improve cooperation of local communities and LOU staff in research activities, and enhance higher level’s understanding on management complications and research needs of the project.

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Appendix (1)

Coordinates of six sample plots for forest dynamics research in Taninthayi Nature Reserve

Sample plot	**Point no.**	**Elevation (m)**	**Coordinates (Degrees WGS 84)**	
			Latitude (N)	**Longitude (E)**
Service Track	101	53.16	14.74778	98.17978
Service Track	102	50.29	14.74778	98.18072
Service Track	103	53.40	14.74819	98.18075
Service Track	104	53.49	14.74819	98.17978
Yebon	201	265.99	14.54662	98.24635
Yebon	202	270.29	14.54687	98.24603
Yebon	203	262.66	14.5475	98.2467
Yebon	204	256.75	14.54731	98.24697
Kyaut Shut	301	264.95	14.60113	98.2126
Kyaut Shut	302	284.46	14.60256	98.2125
Kyaut Shut	303	286.44	14.6019	98.21198
Kyaut Shut	304	264.69	14.60104	98.21207
Heinze	401	548.05	14.4486	98.20734
Heinze	402	541.72	14.44902	98.20715
Heinze	403	543.14	14.44946	98.20793
Heinze	404	559.29	14.44911	98.20811
Thetke Kwet	501	576.25	14.38646	98.20191
Thetke Kwet	502	578.48	14.38657	98.20148
Thetke Kwet	503	604.78	14.38745	98.20141
Thetke Kwet	504	609.09	14.38742	98.20197
Kalone Htar	601	98.89	14.33945	98.24669
Kalone Htar	602	111.22	14.34026	98.24696
Kalone Htar	603	110.12	14.34034	98.24651
Kalone Htar	604	100.86	14.33955	98.24626

Appendix (2)

List of tree species recorded in forest dynamics research of Taninthayi Nature Reserve

Sr. no.	Botanical name	Family	Vernacular name
1	*Acer laurinum* Hassk.	Sapindaceae	yan-myay
2	*Aglaia argentea* Blume	Meliaceae	kyaut-thit-to
3	*Aglaia lawii* (Wight) C.J.Saldanha	Meliaceae	gat-thit-to
4	*Aglaia* sp.	Meliaceae	thit-kyaut-phya
5	*Aglaia spectabilis* (Miq.) S.S.Jain & S.Bennet	Meliaceae	gat-ni
6	*Alangium chinense* (Lour.) Harms	Cornaceae	kant-that
7	*Anisoptera curtisii* Dyer ex King	Dipterocarpaceae	ka-ban
8	*Anisoptera scaphula* (Roxb.) Kurz	Dipterocarpaceae	kaung-hmu
9	*Antidesma ghesaembilla* Gaertn.	Euphorbiaceae	kin-ba-lin
10	*Aphanamixis polystachya* (Wall.) R.Parker	Meliaceae	gat-pok
11	*Aporosa* sp.	Phyllanthaceae	thit-khauk
12	*Archidendron jiringa* (Jack) I.C.Nielsen	Fabaceae	da-nyin
13	*Ardisia polycephala* Wall. ex A.DC.	Primulaceae	kyet-ma-oat
14	*Artocarpus chama* Buch.-Ham.	Moraceae	taung-pein-ne
15	*Artocarpus lacucha* Buch.-Ham.	Moraceae	myauk-lu
16	*Baccaurea ramiflora* Lour.	Phyllanthaceae	ka-na-so
17	*Balakata baccata* (Roxb.) Esser	Euphorbiaceae	taung-ta-yaw
18	*Barringtonia angusta* Kurz	Lecythidaceae	ka-le-ki
19	*Bhesa robusta* (Roxb.) Ding Hou	Centroplacaceae	ta-gu-bok
20	*Boschia mansonii* Gamble	Malvaceae	taw-du-yin
21	*Bouea burmanica* Griff.	Anacardiaceae	ma-yan
22	*Bridelia* sp.	Phyllanthaceae	kyet-che
23	*Buchanania cochinchinensis* (Lour.) M.R.Almeida	Anacardiaceae	lun-san
24	*Butea monosperma* (Lam.) Kuntze	Fabaceae	pauk
25	*Callerya atropurpurea* (Wall.) Schot	Fabaceae	le-zin
26	*Calophyllum* sp.	Calophyllaceae	tha-ra-phy
27	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	yat
28	*Castanopsis argyrophylla* King. ex Hook.f.	Fagaceae	thit-ta
29	*Castanopsis rhamnifolia* (Miq.) A.DC.	Fagaceae	wet-thit-ta
30	*Castanopsis* sp.	Fagaceae	beik-kyan
31	*Chaetocarpus castanocarpus* (Roxb.) Thwaites	Peraceae	hman-ba
32	*Chionanthus ramiflorus* Roxb.	Oleaceae	taw-gant-gaw
33	*Chisocheton* sp.	Meliaceae	gat
34	*Cinnamomum iners* (Reinw. ex Nees & T.Nees) Blume	Lauraceae	hman-thin
35	*Cinnamomum parthenoxylon* (Jack) Meisn.	Lauraceae	ka-ra-way
36	*Cratoxylum neriifolium* (Kurz) Gogelein	Hypericaceae	mat-phe
37	*Croton persimilis* Mull.Arg.	Euphorbiaceae	thet-yin-gyi
38	*Croton robustus* Kurz	Euphorbiaceae	thet-yin
39	*Crypteronia pubescens* Blume.	Crypteroniaceae	yaung-pin
40	*Derris* sp.	Fabaceae	ohn-za
41	*Dialium indum* L.	Fabaceae	taung-ka-ye

Sr. no.	Botanical name	Family	Vernacular name
42	*Dillenia parviflora* Griff.	Dilleniaceae	zin-byun
43	*Diospyros brandisiana* Kurz	Ebenaceae	thit-me
44	*Diospyros malabarica* (Desr.) Kostel.	Ebenaceae	bok
45	*Dipterocarpus alatus* Roxb. ex G.Don	Dipterocarpaceae	ka-nyin
46	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	Dipterocarpaceae	ka-nyin-ywet-gyi
47	*Dipterocarpus turbinatus* C.F.Gaertn.	Dipterocarpaceae	ka-nyin-ni
48	*Donella lanceolata* (Blume) Aubrév.	Sapotaceae	tha-gya-pin
49	*Duabanga grandiflora* (Roxb. ex DC.) Walp.	Lythraceae	myauk-ngo
50	*Dysoxylum grande* Hiern.	Meliaceae	gat-phyu
51	*Dysoxylum procerum* Hiern.	Meliaceae	gat-phwe
52	*Eugenia* sp. (1)	Myrtaceae	tha-byae
53	*Eugenia* sp. (2)	Myrtaceae	tha-byae-o-kye
54	*Euonymus indicus* B.Heyne ex Wall.	Celastraceae	thit-gya-boe
55	*Fernandoa adenophylla* (Wall. ex G.Don) Steenis	Bignoniaceae	phet-than
56	*Ficus fistulosa* Reinw. ex Blume	Moraceae	tha-phan
57	*Ficus hispida* L.f.	Moraceae	kha-aung
58	*Ficus racemosa* L.	Moraceae	ye-tha-phan
59	*Ficus semicordata* Buch.-Ham. ex Sm.	Moraceae	ka-dut
60	*Firmiana colorata* (Roxb.) R.Br.	Malvaceae	wet-shaw
61	*Flacourtia jangomas* (Lour.) Raeusch.	Salicaceae	kyet-yoe
62	*Garcinia celebica* L.	Clusiaceae	je-chin
63	*Gardenia sootepensis* Hutch.	Rubiaceae	yin-khat
64	*Gardenia* sp.	Rubiaceae	hman
65	*Gluta* sp.	Anacardiaceae	chi
66	*Gluta tavoyana* Hook.f.	Anacardiaceae	taw-tha-yet
67	*Gluta usitata* (Wall.) Ding Hou	Anacardiaceae	thit-si
68	*Gnetum gnemon* L.	Gnetaceae	taw-hin-cho
69	*Gonocaryum lobbianum* (Miers) Kurz	Cardiopteridaceae	wun-the-chay
70	*Grewia polygama* Roxb.	Malvaceae	ta-yaw
71	*Heritiera javanica* (Blume) Kosterm.	Malvaceae	kan-zo
72	*Hibiscus macrophyllus* Roxb. ex Hornem.	Malvaceae	phet-wun-gyi
73	*Holarrhena pubescens* Wall. ex G. Don.	Apocynaceae	let-htoke
74	*Hopea helferi* (Dyer) Brandis	Dipterocarpaceae	kyaut-thin-gan
75	*Hopea odorata* Roxb.	Dipterocarpaceae	thin-gan
76	*Jatropha glandulifera* Roxb.	Euphorbiaceae	kyet-su
77	*Knema angustifolia* (Roxb.) Warb.	Myristicaceae	kywe-thwe
78	*Lagerstroemia floribunda* Jack	Lythraceae	kha-maung-phyu
79	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae	pyin-ma
80	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	lan-thone
81	*Leea indica* Merr.	Vitaceae	na-ga-mauk
82	*Licuala spinosa* Wurmb	Arecaceae	sa-lu
83	*Litsea grandis* (Nees) Hook.f.	Lauraceae	kyaut-ta-gu
84	*Litsea laurifolia* (Jacq.) Kurz.	Lauraceae	on-don

Sr. no.	Botanical name	Family	Vernacular name
85	*Litsea* sp.	Lauraceae	ta-gu
86	*Macaranga denticulata* (Blume) Mull.Arg.	Euphorbiaceae	phet-wun
87	*Madhuca longifolia* (J.Koenig ex L.) J.F.Macbr.	Sapotaceae	kan-zaw
88	*Madhuca longifolia* var. *latifolia* (Roxb.) A.Chev.	Sapotaceae	ta-lin-thone
89	*Magnolia champaca* (L.) Baill. ex Pierre	Magnoliaceae	san-kha
90	*Magnolia liliifera* (L.) Baill.	Magnoliaceae	bau-san-kha
91	*Mangifera caloneura* Kurz	Anacardiaceae	tha-yet
92	*Mangifera* sp.	Anacardiaceae	tha-yet-kha
93	*Memecylon grande* Retz.	Melastomataceae	taung-byuu
94	*Mesua ferrea* L.	Calophyllaceae	gant-gaw
95	*Millettia glaucescens* Kurz	Fabaceae	pyin-bo
96	*Mitragyna parvifolia* (Roxb.) Korth.	Rubiaceae	htein
97	*Monoon hookeriana* (King) B.Xue & R.M.K.Saunders	Annonaceae	taung-bok
98	*Monoon simiarum* (Buch.-Ham. ex Hook.f. & Thomson) B.Xue & R.	Annonaceae	tha-but
99	*Morinda citrifolia* L.	Rubiaceae	bu-pin
100	*Neolamarckia cadamba* (Roxb.) Bosser	Rubiaceae	ma-u
101	*Neonauclea excelsa* (Blume.) Merr.	Rubiaceae	thit-pha-yaung
102	*Nephelium laurinum* Blume.	Sapindaceae	taw-kyet-mauk
103	*Nephelium ramboutan-ake* (Labill.) Leenh.	Sapindaceae	kyet-mauk-wa
104	*Nephelium* sp.	Sapindaceae	kyet-mauk
105	*Nephelium* sp. (2)	Sapindaceae	ye-kyet-mauk
106	*Oroxylum indicum* (L) Kurz	Bignoniaceae	kyaung-sha
107	*Palaquium obovatum* (Griff.) Engl.	Sapotaceae	pan-le-byin
108	*Parashorea stellata* Kurz	Dipterocarpaceae	ka-dut-net
109	*Parkia leiophylla* Kurz.	Fabaceae	shan-da-nyin
110	*Pavetta indica* L.	Rubiaceae	myet-na-pan
111	*Payena lucida* A.DC.	Sapotaceae	zin-swe
112	*Pentace griffithii* King	Malvaceae	thit-sho
113	*Phanera sulphurea* (C.E.C.Fisch.) Thoth.	Fabaceae	swe-daw
114	*Phoebe tavoyana* Hook.f.	Lauraceae	kye-ze
115	*Phyllanthus albizzioides* (Kurz) Hook. f.	Phyllanthaceae	shit-kha
116	*Phyllanthus emblica* L.	Phyllanthaceae	zi-phyu
117	*Podocarpus neriifolius* D.Don	Podocarpaceae	ye-thit-min
118	*Pterocymbium* sp.	Sterculiaceae	moe-pin
119	*Pterospermum acerifolium* (L.) Willd.	Malvaceae	taw-karamet
120	*Sageraea bracteolata* R.Parker	Annonaceae	pa-ngan
121	*Sandoricum koetjape* (Burm.f.) Merr.	Meliaceae	thit-to
122	*Sandoricum* sp.	Meliaceae	taw-thit-to
123	*Schima wallichii* (DC.) Korth.	Theaceae	thit-yah
124	*Shorea obtusa* Wall. ex Blume	Dipterocarpaceae	thit-ya
125	*Shorea* sp.	Dipterocarpaceae	phut-ma-tet
126	*Shorea* sp. (2)	Dipterocarpaceae	taung-thin-gan
127	*Spondias pinnata* (L.f.) Kurz	Anacardiaceae	gway

Sr. no.	Botanical name	Family	Vernacular name
128	*Sterculia* sp.	Malvaceae	shaw
129	*Sterculia versicolor* Wall.	Malvaceae	shaw-phyu
130	*Stereospermum fimbriatum* (Wall. ex G.Don) DC.	Bignoniaceae	than-that
131	*Suregada multiflora* (A.Juss.) Baill.	Euphorbiaceae	lay-min
132	*Swintonia floribunda* Griff.	Anacardiaceae	taung-tha-yet
133	*Syzygium albiflorum* (Duthie & Kurz) Bahadur & R.C.Gaur.	Myrtaceae	tha-byae-o-si
134	*Syzygium oblatum* (Roxb.) Wall. ex A.M.Cowan & Cowan	Myrtaceae	tha-byae-ni
135	*Syzygium* sp. (1)	Myrtaceae	tha-byae-pyar
136	*Syzygium* sp. (2)	Myrtaceae	tha-byae-ohn
137	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	thit-seint
138	*Terminalia catappa* L.	Combretaceae	taw-ban-da
139	*Terminalia chebula* Retz.	Combretaceae	phan-kha
140	*Terminalia* sp.	Combretaceae	khan-lein
141	*Tetrameles nudiflora* R.Br.	Tetramelaceae	thin-phuu
142	*Toona hexandra* (Wall.) M.Roem.	Miliaceae	thit-ka-doe
143	*Ulmus lanceifolia* Roxb.	Ulmaceae	tha-le-gyi
144	unknown 1		bwa
145	unknown 2		byit-phat
146	unknown 3		hti
147	unknown 4		phyu-gyi
148	unknown 5		taung-bwa
149	unknown 6		taung-pan-thi
150	unknown 7		unknown7
151	unknown 8		unknown8
152	unknown 9		unknown9
153	unknown 10		unknown10
154	unknown 11		unknown11
155	*Vitex peduncularis* Wall. ex Schauer	Lamiaceae	pa-zin-ngo
156	*Xanthophyllum lanceatum* (Miq.) J.J.Sm.	Polygalaceae	thit-phyu
157	*Zanthoxylum rhetsa* (Roxb.) DC.	Rutaceae	ma-ya-nin

Appendix (3)

List of tree regeneration species recorded in forest dynamics research in Taninthayi Nature Reserve

Sr. no.	Botanical name	Family	Vernacular name
1	*Aglaia lawii* (Wight) C.J.Saldanha	Meliaceae	gat-thit-to
2	*Aglaia spectabilis* (Miq.) S.S.Jain & S.Bennet	Meliaceae	gat-ni
3	*Anisoptera scaphula* (Roxb.) Kurz	Dipterocarpaceae	kaung-hmu
4	*Aphanamixis polystachya* (Wall.) R.Parker	Meliaceae	gat-pok
5	*Aporosa* sp.	Phyllanthaceae	thit-khauk
6	*Archidendron jiringa* (Jack) I.C.Nielsen	Fabaceae	da-nyin
7	*Artocarpus chama* Buch.-Ham.	Moraceae	taung-pein-ne
8	*Baccaurea ramiflora* Lour.	Phyllanthaceae	ka-na-soe
9	*Barringtonia angusta* Kurz	Lecythidaceae	ka-le-ki
10	*Bridelia* sp.	Phyllanthaceae	kyet-che
11	*Callerya atropurpurea* (Wall.) Schot	Fabaceae	le-zin
12	*Cinnamomum iners* (Reinw. ex Nees & T.Nees) Blume	Lauraceae	hman-thin
13	*Croton persimilis* Mull.Arg.	Euphorbiaceae	thet-yin-gyi
14	*Derris* sp.	Fabaceae	ohn-za
15	*Dillenia parviflora* Griff.	Dilleniaceae	zin-byun
16	*Diospyros brandisiana* Kurz	Ebenaceae	thit-me
17	*Diospyros malabarica* (Desr.) Kostel.	Ebenaceae	bok
18	*Dipterocarpus alatus* Roxb. ex G.Don	Dipterocarpaceae	ka-nyin
19	*Duabanga grandiflora* (Roxb. ex DC.) Walp.	Lythraceae	myaunt-ngo
20	*Eugenia* sp. (1)	Myrtaceae	tha-byae
21	*Euonymus indicus* B.Heyne ex Wall.	Celastraceae	thit-kya-boe
22	*Fernandoa adenophylla* (Wall. ex G.Don) Steenis	Bignoniaceae	phet-than
23	*Ficus fistulosa* Reinw. ex Blume	Moraceae	tha-phan
24	*Ficus semicordata* Buch.-Ham. ex Sm.	Moraceae	ka-dut
25	*Garcinia microstigma* Kurz	Hypericaceae	taung-thale
26	*Gluta* sp.	Anacardiaceae	chi
27	*Gluta tavoyana* Hook.f.	Anacardiaceae	taw-tha-yet
28	*Gnetum gnemon* L.	Gnetaceae	taw-hin-cho
29	*Gonocaryum lobbianum* (Miers) Kurz	Cardiopteridaceae	wun-the-chay
30	*Hopea odorata* Roxb.	Dipterocarpaceae	thin-gan
31	*Knema angustifolia* (Roxb.) Warb.	Myristicaceae	kywe-thwe
32	*Leea indica* Merr.	Vitaceae	na-ga-mauk
33	*Licuala spinosa* Wurmb	Arecaceae	sa-lu
34	*Litsea* sp.	Lauraceae	ta-gu
35	*Macaranga denticulata* (Blume) Mull.Arg.	Euphorbiaceae	phet-wun
36	*Magnolia champaca* (L.) Baill. ex Pierre	Magnoliaceae	san-kha
37	*Mesua ferrea* L.	Calophyllaceae	gant-gaw
38	*Morinda citrifolia* L.	Rubiaceae	bu-pin
39	*Neolamarckia cadamba* (Roxb.) Bosser	Rubiaceae	ma-u

Sr. no.	Botanical name	Family	Vernacular name
40	*Neonauclea excelsa* (Blume.) Merr.	Rubiaceae	thit-pha-yaung
41	*Nephelium laurinum* Blume.	Sapindaceae	taw-kyet-mauk
42	*Nephelium* sp.	Sapindaceae	kyet-mauk
43	*Palaquium obovatum* (Griff.) Engl.	Sapotaceae	pan-le-pyin
44	*Parashorea stellata* Kurz	Dipterocarpaceae	ka-dut-net
45	*Parkia leiophylla* Kurz.	Fabaceae	shan-da-nyin
46	*Pentace griffithii* King	Malvaceae	thit-sho
47	*Phyllanthus emblica* L.	Phyllanthaceae	zi-phyu
48	*Podocarpus wallichianus* Presl	Podocarpaceae	thit-min
49	*Sandoricum koetjape* (Burm.f.) Merr.	Meliaceae	thit-to
50	*Shorea* sp.	Dipterocarpaceae	phut-ma-tet
51	*Spondias pinnata* (L.f.) Kurz	Anacardiaceae	gway
52	*Swintonia floribunda* Griff.	Anacardiaceae	taung-tha-yet
53	*Syzygium albiflorum* (Duthie & Kurz) Bahadur & R.C.Gaur.	Myrtaceae	tha-byae-o-si
54	*Syzygium oblatum* (Roxb.) Wall. ex A.M.Cowan & Cowan	Myrtaceae	tha-byae-ni
55	*Syzygium* sp. (2)	Myrtaceae	tha-byae-ohn
56	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	thit-seint
57	*Terminalia chebula* Retz.	Combretaceae	phan-kha
58	Unknown 1		ma-kha-lay
59	Unknown 2		sin-min
60	Unknown 3		myit-ka-le
61	*Xanthophyllum lanceatum* (Miq.) J.J.Sm.	Polygalaceae	thit-phyu
62	*Zanthoxylum rhetsa* (Roxb.) DC.	Rutaceae	ma-ya-nin

Appendix (4)

Pictures of the sample plots in the field survey of Forest Dynamics Research (2019) in Taninthayi Nature Reserve

Invasion of wild bananas, shrubs and weeds in the existing permanent sample plot at Service Track (ST) after intense disturbance by logging and consequent fires within the last three years.

Existing permanent sample plot at Yebon (YB)

Existing permanent sample plot at Kyaut Shut (KS)

Permanent sample plot newly established at Heinze (HZ) in 2019

Newly established sample plot at Thetke Kwet (TKK) in 2019

Newly established sample plot at Kalone Htar (KLH) in 2019