Final Report for

Forest Dynamics Research on Endemic Tree Species in Tanintharyi Nature Reserve Forest

For the Period of December (2010 to 2012)

By

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CONTENTS

Summary

To realize the forest dynamic of endemic tree species in the TNR forest, three permanent plots (50x100m) in different sites (8.6 point, Kyauk-shut, and Yebon) were set up and observed during December 2010 to December 2012. During the course of the study, the plots were enumerated for first time in December 2010 and February 2011, checking the first enumeration were done in July 2012, second enumeration were conducted in December 2012. Almost 783 trees (≥ 10cm gbh) these being 100 species representing 59 genera, 32 families in 8.6 point, 894 trees (≥ 10cm gbh) these being 130 tree species, 79 genera, 38 families in Kyauk-shut, and 934 trees (≥ 10cm gbh) these being 129 tree species, 70 genera, 37 families in Yebone were examined. These were scored for death or alive status and alive trees were measured for gbh. Trees recruiting above the 10 cm gbh were included into the population. With the variable measured in the field, dynamics could be assessed in terms of growth, mortality, recruitment and species composition.

The structure of the forest changed in respect to density and basal area: generally increasing in second enumeration (except in Yebone, density was decline in second enumeration). Although some species dropped out, some species recruited the population and overall diversity hardly changed. With increasing size classes, Shannon's index decreased and lowest for large trees ≥ 100cm gbh. The dominant families of tree species were Meliaceae, Euphorbiaceae, Lauraceae, Rubiaceae, Myrtaceae, and Annonaceae in all study sites.

Though mortality and recruitment rates were high in 8-6 point and Kyauk-shut (m_a: 2.06% y^{-1}, 2.04 % y^{-1}; r_a: 4.72 % y^{-1}, 3.56 %y^{-1}), mortality and recruitment rates were low in Yebone (m_a 1.19; r_a 0.45 % y^{-i}). Family Lauraceae was high mortality rate among the families in all study sites. Mean relative growth rate was high in 8-6 point and Kyauk-shut (22.25 mm m^{-1} y^{-1}, 22.10 mm m^{-1} y^{-1}) and low in Yebone (15.47mm m^{-1} y^{-1}).

After the exclusion of unreliable gbh measurements at second enumeration, the calculation of absolute growth rate produced 684, 819, and 904 individuals in 8-6 point, Kyauk-shut, and Yebone. Mean absolute growth rate was 9.62 mm y^{-1}, 10.54 mm y^{-1}, 5.33 mm y^{-1} in 8-6 point, Kyauk-shut and Yebone respectively.

1. Introduction

Myanmar is a tropical country located in Southeast Asia; between 9˚32' and 28˚31' North latitude and between 92˚ 10' and 101˚ 11' East longitude. In the Asia-Pacific region, Myanmar stands out favorably with her large cover of forest. Natural forests in Myanmar are classified as mangroves and estuarine forests in the delta region; deciduous and dipterocarps forests in the region with pronounced dry season; evergreen forest in the areas of high moisture and rainfall; hill evergreen and sub-alpine forests in high altitudes subtropical regions (Forest Dept., 2006).

From biodiversity conservation point of view TNR lies within "Biounit 5d (Uga, 2006), and Tenasserim-South Thailand semi-evergreen moist forest region. The area has been identified by WWF as one of the threatened terrestrial ecosystems of the world and particularly as this area is connected to the Western Forest Complex of Thailand, it will be of significance for one of the important trans-border protected areas in Asia.

The dynamic nature of ecosystems has been recognized by ecologists, change being the normal course of events. Consequently, even without direct human interference, which may feed back on regional climate, tropical rain forests are neither stable nor unchanging. There is no competitive equilibrium (which would lead to increasing extinctions of species and eventually low diversity) among organisms and no equilibrium of the community with the environment (Huston 1994), “uniform stable environments never exist in nature” (Huston 1979). The environment of tropical rain forests variable over longer time scales (Newbery *et al*. 1999a) and their highly diverse tree communities “are unlikely to be constant in their species composition, or to show stable equilibria in their dynamics” (Newbery *et al*.1999b). Instead, a dynamic equilibrium between low rates of competitive displacement and a moderate to low frequency of disturbance has been postulated (Huston 1979, 1994, Newbery *et al*. 1999b) Adding to the dynamics at the species level in a state on non-equilibrium is that the composition of a forest in any one location is highly special and dependent on its local history including climate, site and biogeography.

Therefore, if the term equilibrium implies the tendency of an ecosystem to show similar characteristics in terms of biomass, structure and species composition on average over long time scales (decade to centuries) and/or larger spatial scales, dynamic equilibrium may be exhibited by ecosystems (Connell and Sousa 1983, Newbery *et al*. 1999b). The dynamism is then triggered by forced (internal or external) which may affect growth by deceleration, damage or removal and the following responses of the vegetation. These may be either resistance (unaffected), persistence (the ability to tolerate stress – conditions when resources are below the optimum or they cannot be utilized optimally – across extended periods) or resilience (the ability to recover within time before the next negative force operates) or a substantially change (gradual or rapid) to the vegetation. These disturbances drive the dynamic nature of ecosystems and their interactions with the vegetation are essential to the understanding of ecological processes.

Several studies on flora and fauna at the vicinity of the gas pipelines were conducted in the surrounding of project area, such as vegetation and vascular flora study along the Yetagun-Yadana pipeline (Maxwell, J. F., 2001), vegetation and biodiversity study in Yadana project area (Francis H.J. Crome, 1996), and flora survey in TNR Forest (Hla Maung Thein, 2007). Though flora and fauna survey in TNR was conducted by many investigators, the information concerning with TNR is still need to explore. The disappearance of tropical rain forests comes at a time when our knowledge on their structure and dynamics is woefully inadequate. For this reason, the recent exploration is emphasis on forest dynamics, which has never done in TNR.

2. Study area

The location of Tanintharyi Nature Reserve Forest is 14° 20' 50" to 14° 57' 55" north latitude and 98° 05' 10" to 98° 31' 32" east longitude. TNR was established and legally notified by MOF on the 30th of March 2005 with the aim at conserving tropical rainforests and their constituent biodiversity in the Tanintharyi region of southern Myanmar. It consists of the eastern part of Heinze / Kaleinaung Reserve Forest 85,728 ha and Luwaing Reserve Forest 84,273 ha. This area encompasses 170,000 ha of primarily pristine tropical evergreen forest and some mixed deciduous forest. The size of this area is comparable to the largest protected areas in other countries of the region and the extensive forests make it a significant addition to both Myanmar's Protected Areas System (PAS) and the regional protected areas network. The study site lies near the 8-6 point, Kyauk-shut, and Yebon. (figure 1).

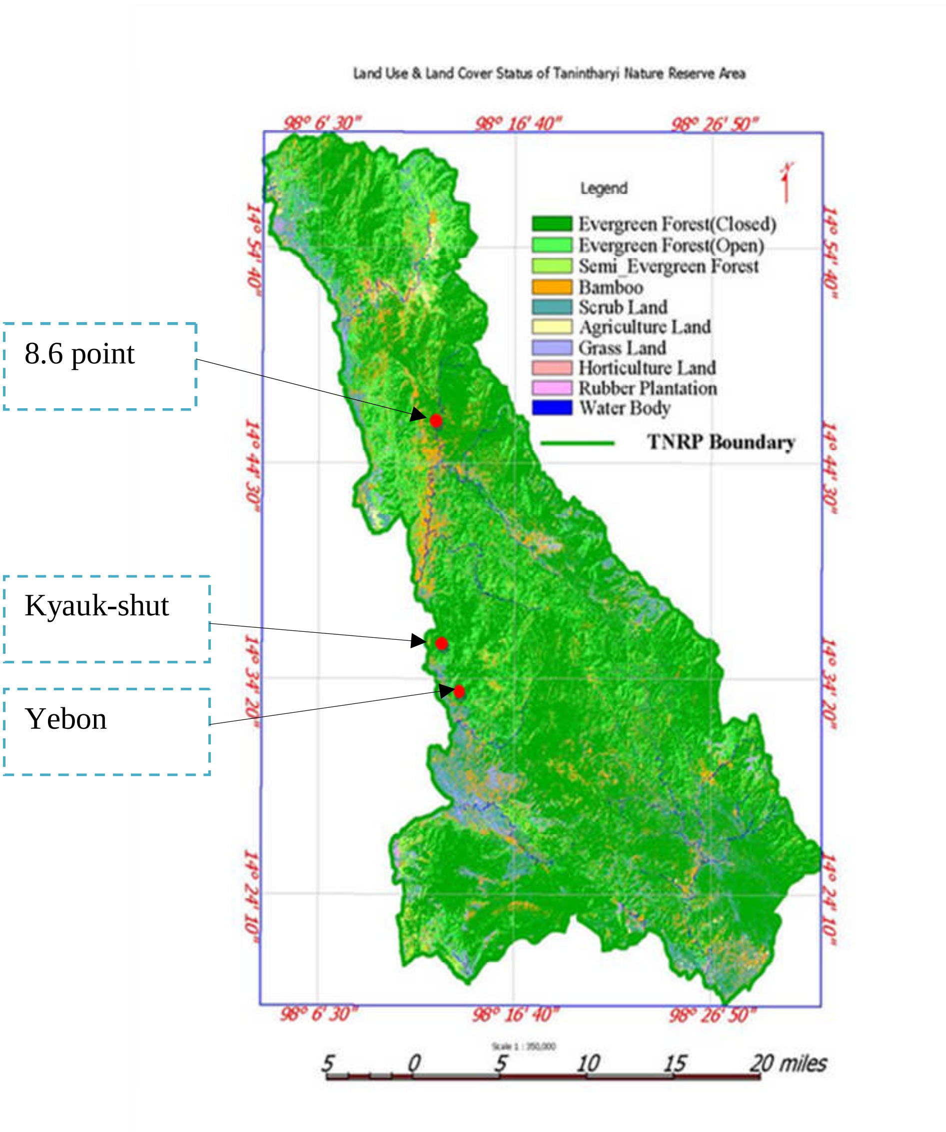


Figure (1) Location map of the study area

2.1 Climate

The climate in Tanintharyi Nature Reserve area is seasonal and tropical monsoon type. It may be described as wet and generally intermediate between that of the rest of the whole Myanmar and Malay Peninsula rather than upper Myanmar. Owing to the proximity of the sea, very high temperature are seldom experienced and cool wind blows throughout the most year. The rains usually start at the end of April and continue until about the middle of November and showers and slight storms are liable to occur at any time during December and March. The so-called cold weather is of very short duration confined to January only. Due to cool wind from sea, the nights however are cool almost throughout the dry season.

Average annual rain-fall during 2006 to 2010 was 5408.2mm and maximum rainfall occurs in July and August (table 1, figure 2). Monthly mean temperature and mean relative humidity were shown in table 2, 3 and figure 3, 4.

Table (1) Monthly and annual mean rainfall during 2006 to 2010 in the study area

Month	Rainfall (mm) 2006	Rainfall (mm) 2007	Rainfall (mm) 2008	Rainfall (mm) 2009	Rainfall (mm) 2010	Annual mean rainfall (mm)
January	0	1	0	0	31	6.4
February	24	0	52	0	0	15.2
March	67	0	47	47	0	32.2
April	215	117	188	283	3	161.2
May	759	610	975	416	411	634.2
June	738	620	1026	1223	302	781.8
July	2081	1460	1038	1925	595	1419.8
August	1880	1228	766	903	832	1121.8
September	604	815	1149	1107	417	818.4
October	448	454	259	440	381	396.4
November	0	7	51	6	trace	12.8
December	0	0	0	0	40	8
Total	6816	5312	5551	6350	3012	5408.2

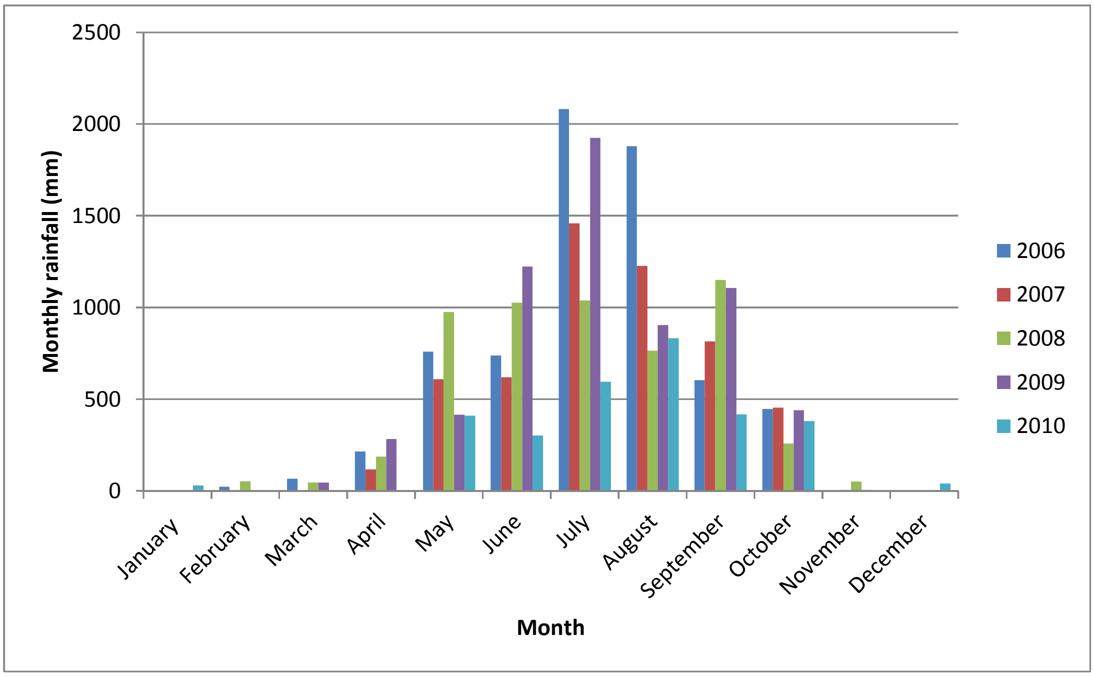


Figure (2) Monthly rainfall during 2006 to 2010 in the study area

Table (2) Monthly mean temperature during 2006 to 2010 in the study area

Month	Monthly mean temperature (°C) 2006	Monthly mean temperature (°C) 2007	Monthly mean temperature (°C) 2008	Monthly mean temperature (°C) 2009	Monthly mean temperature (°C) 2010
January	26.4	26.7	26.4	24.6	27.5
February	28.2	26.5	27.5	27.7	28.1
March	29.2	27.9	27.9	29	28.8
April	28.8	29.6	29	28.8	30.5
May	27.7	27.4	25.8	27.2	29.7
June	26.4	27.3	26.1	25.5	28
July	25	25.6	25.5	24.7	27.3
August	24.8	25.3	26.2	26	26.8
September	26.5	25.8	25	25.3	27.4
October	27.5	27.3	27.8	26	27
November	28	26.2	26.7	27	27.2
December	26.2	26.2	24.9	26.4	26.6

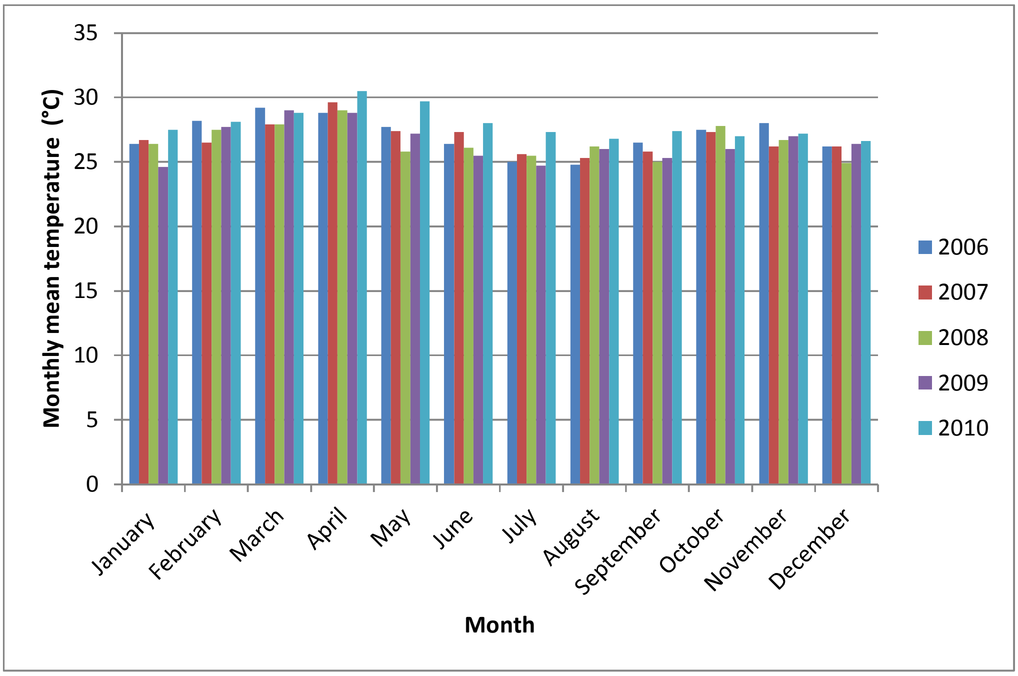


Figure (3) Monthly mean temperature during 2006 to 2010 in the study area

Table (3) Mean relative humidity and average relative humidity during 2006 to 2010 in the study area

Month	Mean relative humidity (%) 2006	Mean relative humidity (%) 2007	Mean relative humidity (%) 2008	Mean relative humidity (%) 2009	Mean relative humidity (%) 2010	Average relative humidity (%)
January	68	64	65	60	75	66.4
February	67	62	71	72	73	69
March	73	65	71	73	71	70.6
April	73	72	77	78	69	73.8
May	88	90	94	89	78	87.8
June	90	81	93	98	88	90
July	100	95	96	98	90	95.8
August	98	96	91	91	92	93.6
September	91	94	93	93	85	91.2
October	85	81	84	89	86	85
November	70	66	69	71	71	69.4
December	65	67	63	70	75	68

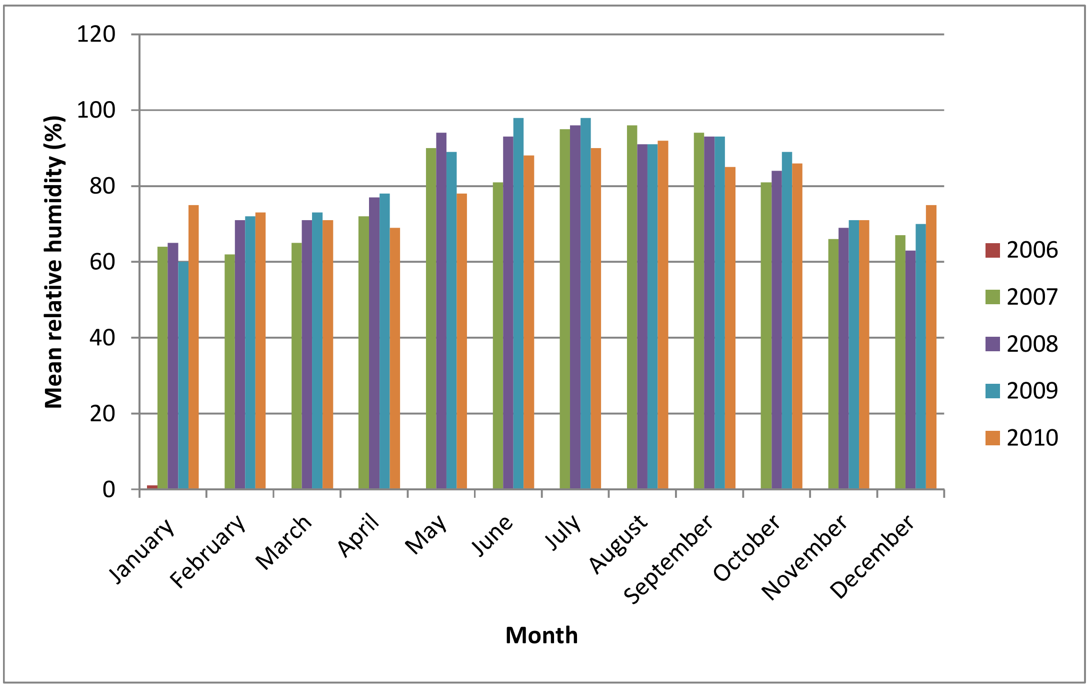


Figure (4) Mean relative humidity during 2006 to 2010 in the study area

2.2 Topography and geology

The area of TNR is generally hilly along the Thai border area and most of the southern portions are mountainous. The mountain range runs from north to south while the slope rises from west to east towards the ridge top and is oriented to the western aspect. Most areas in TNR are of high elevation and the range of the terrain varies from 15m above sea level in low land to 1400m at the ridge of the border.

The three geological formations are found in the area of Tanintharyi Nature Reserve: (1) granite intrusions (2) the Mergui Series of Sedimentary rocks and (3) recent and sub recent alluvial deposits (H.C Smith-1926). The large masses of granite intruded into the oldest rocks which were the metamorphosed and folded sedimentary deposits. The sedimentary rocks had been eroded and exposed the granite elsewhere in the area. Frequently these sedimentary rocks cover the granite even on the hill tops but all the ranges of hills are of granite beneath.

3. Objectives

The present study has two main objectives. The first one is an attempt to clarify the forest structure, floristic composition and diversity of tree species; the second is by assessing the dynamics in terms of growth, mortality, recruitment, and species composition in Tanintharyi Nature Reserved Forest.

4. Methodology

4.1 Plot setup and first enumeration

To understand the dynamics of endemic species in the TNR forest, three permanent plots (50x100m in size) in different sites (8.6 point, Kyauk-shut, and Yebon) were set up and observed during December 2010 to December 2012. The main plot is subdivided into 50 10x10m subplots and their corner marked with posts. Subplots were labeled by 10 rows (with letters) and five columns (with numbers; e.g. E4 has the coordinates x_1=40; y_1=30; x_2=50, y_2=40) see figure (5).

After plot set up enumeration is conducted. Within each subplot, every living tree with a minimum girth at breast height (gbh) of 10cm is mapped to the nearest 0.1m and its coordinates are recorded different symbols for size classes and dead trees, labeled with tree numbers. The trees are permanently marked with unique numbered aluminum tag.

Tags are attached to tree with nylon fishing line using a slip-knot system to allow the sling to increase its size with tree growth. Only in the case of very large trees, is the tag nailed to the tree. The point of measurement is marked by a permanent marker pen at 1.3m above the ground (or above any buttresses; the size of a tree at the point of measurement will then still be referred to as the gbh, i.e. this term is equivalent to a reference height) and trees are measured for gbh to the nearest mm over the paint mark.

Botanical specimens are taken – except for very common and in the field reliably identified species. The families were identified by using key to the families of the flowering plants, issued by Department of Botany, Yangon University (1994). Specimen identification was performed with the use of literatures by Backer *et a*l., (1963, 1965, 1968), Hooker, Sir J.D. Vol.(I-VII), (1897) and Hundley, H.G. and Chit Ko Ko (1961).

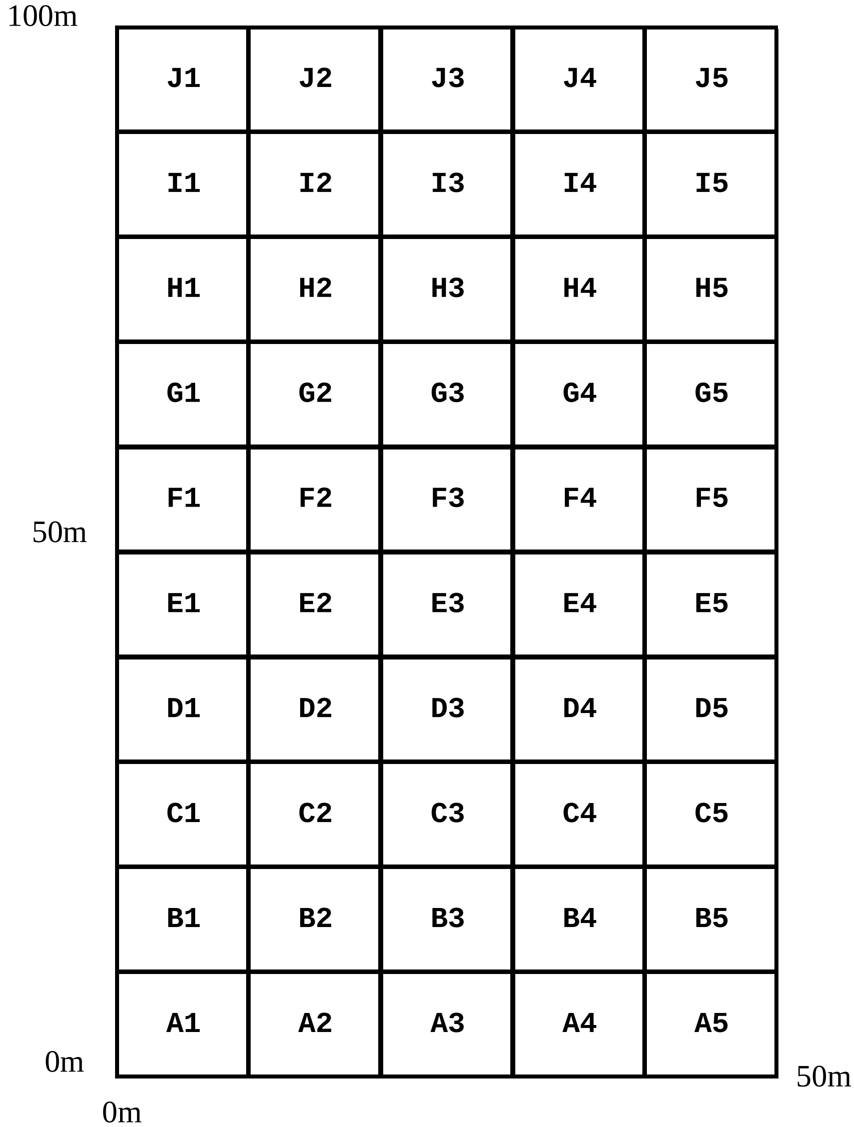


Figure (5) Setup of three main plots at TNR forest and 10x10m subplots are shown with their labels

4.2 Checking the first measurement

Complete re-measurement of the three main plots was carried out in June 2012 after initial establishment, as a check on the accuracy of the surveying and linear measurement, as well as the tree data. In addition we performed an intensive inspection of uncertain taxa in the primary forest plots to further improve the quality of the state of the taxonomic identification. Specimens of that inspection were collected, dried and taken to Yangon to collate the material with that of the previous enumerations for identification and to keep the vouchers store.

4.3 Second enumeration

Between December 2012 and January 2013, the second enumeration of the main plots was performed. All trees (i.e. those ≥10cm gbh) of the first enumeration were revisited with the help of maps (one per subplot) drawn from the tree coordinates that were recorded in first enumeration. Every tree was inspected and if it was alive, gbh was measure. Trees that were not recorded previously but reached a gbh of ≥10cm were recorded as new recruits (tag with a new number), their gbh was recorded and coordinates were taken.

4.4 Definition of periods

Table 4 shows the lengths of time interval between enumerations based on all trees that had a date both at the start and end of the interval. Calculation of mortality and recruitment rates on the plot, for species or size classes were done with mean intervals of each individual group.

Table (4) Length of time interval between enumerations, showing numbers of trees (n) and mean interval length (t) for 8-6 point, Kyauk-shut, and Yebone.

	2010-2012		
	8-6 point	Kyauk-shut	Yebone
n	783	894	934
interval length t (d)	722	688	686
interval length t (y)	1.98	1.88	1.88

4.5 Mortality and recruitment rate

Period mortality and recruitment rates (%) were calculated from the following equations: (Alder 1995, Sheil *et. al.,* 1995)

$$\text{mortality:} \quad m_p = \frac{n_d}{n_{start}} \text{x}100$$

$$\text{recruitment:} \quad r_p = \frac{n_{rec}}{n_{start}} \text{x}100$$

m_p= period mortality rates, r_p= period recruitment rates, n_d= number of dead tree, n_{start}=number of all trees at start, m_{rec}= number of recruits

4.6 Growth rates

Stem growth rate were found as follow (Hunt 1990, Alder 1995)

absolute growth rate (agr) in mm y^{-1}

$$agr = \frac{(gbh_{end}\text{-}gbh_{start})}{t} \text{x}10$$

relative growth rate (rgr) in mm m^{-1} y^{-1}

$$rgr = \frac{(\ln(gbh_{end})\text{-}\ln(gbh_{start})}{t} \text{x}10^3$$

with gbh_{start} and gbh_{end} being the gbh (in cm) at the start and at the end of a time interval (t, in y) respectively.

Definition of valid trees for growth calculation

Growth rates were calculated only if the following conditions applied: for second enumeration every tree was reviewed for reliability of its measurements and assigned a code 1= valid, code 0 = invalid. Assessed as not being reliable and therefore invalid for growth calculation were the tree was broken below, half broken or death at the point of mark, or had lost one or more multiple stems. Growth was then calculated with those trees that were valid both at the start and end of an interval. From the resulting rates, some trees had to be additional excluded because they had negative growth rates below an operational threshold.

4.7 Diversity measures

Species diversity is expressed by two Shannon – Wiener index (H), Evenness (E). Magurran (1988).

$$H = -\sum_{i=1}^{s} (P_i)(\log_2 P_i)$$

Evenness was calculated by Shannon – Wiener function (1963), as follow:

$$E = \frac{H}{H_{max}} \qquad H_{max} = \mathrm{Log}_2\, S$$

H = index of species diversity

S = number of species

P_i = proportion of total sample belonging to the i th species.

E = evenness (range 0 – 1)

H_{max}= species diversity under conditions of maximal equitability

4.8 Size classes

Analysis within different sizes was performed on the following gbh limits:

≥10cm gbh (≥3.2 cm dbh)	= all trees
10- <50 cm gbh (3.2cm - < 15.9 cm dbh)	= small tree
50- <100 cm gbh (15.9cm - < 31.8 cm dbh)	= medium tree
≥100cm gbh (≥ 31.8 cm dbh)	= large tree

5. Results

5.1 Structure

5.1.1 Tree numbers

The main plot in 8-6 point in 2010, December consisted of 742 trees with a gbh of ≥10cm. In 2012 December, 30 trees were recorded as death. A total of 71 new trees recruiting into the population (i.e reaching ≥10cm gbh) were recorded.

The main plot in Kyauk-shut in 2011, February consisted of 868 trees with a gbh of ≥10cm. In 2012 December, 33 trees were recorded as death. A total of 59 new trees recruiting into the population (i.e reaching ≥10cm gbh) were recorded.

The main plot in Yebone in 2011, February consisted of 947 trees with a gbh of ≥10cm. In 2012 December, 21 trees were recorded as death. A total of 8 new trees recruiting into the population (i.e reaching ≥10cm gbh) were recorded.

According to the results of second enumeration 8-6 point had more recruits than other two sites and Yebone had least recruits and death (table-5).

Table (5) Tree numbers in the main plot at 8-6 point, Kyauk-shut, and Yebone. At the start and at the end of the period 2010 to 2012

	Period- 2010 to 2012		
	8-6 point	Kyauk-shut	Yebone
n_{start}	742	868	947
n_d	30	33	21
n_{rec}	71	59	8
n_{end}	783	894	934

n_{start}=number of all trees at start, n_d= number of dead tree, m_{rec}= number of recruits

n_{end}=number of all trees at end

5.1.2 Density and basal area

The density of tree in main plot of 8-6 point in 2010 December was 1484ha^{-1} (table-6). Almost 91.37% of these were between 10 and 50 cm gbh (1356ha^{-1}), 2.29% (34 ha^{-1}) were ≥100cm gbh (figure-6). There were 142 recruits ha^{-1} and 60 death ha^{-1} (table-6). Average basal area of 8-6 point in 2010 December was 31.85 m^{-2}ha^{-1} (table-7). Small trees contribute 22.07% (7.03 m^{-2}ha^{-1}), medium-sized trees 11.05% (3.52 m^{-2}ha^{-1}), and large trees 66.88% (21.3 m^{-2}ha^{-1}) to the total basal area (figure-7). In 2012, 0.21 m^{-2}ha^{-1} were gained through recruits and 0.8 m^{-2}ha^{-1} were lost through death.

The density of tree in main plot of Kyauk-shut in 2011 February was 1736ha^{-1} (table-6). Almost 83.53% of these were between 10 and 50 cm gbh (1736ha^{-1}), 4.49% (78 ha^{-1}) were ≥100cm gbh (figure-6). There were 118 recruits ha^{-1} and 66 death ha^{-1} (table-5). Average basal area of Kyauk-shut in 2011 February was 35.58 m^{-2}ha^{-1} (table-7). Small trees contribute 17.28% (6.15 m^{-2}ha^{-1}), medium-sized trees 23.55% (8.38 m^{-2}ha^{-1}), and large trees 59.16% (21.05 m^{-2}ha^{-1}) to the total basal area (figure-7). In 2012, 0.12 m^{-2}ha^{-1} were gained through recruits and 0.4 m^{-2}ha^{-1} were lost through death.

The density of tree in main plot of Yebone in 2011 February was 1894ha^{-1} (table-6). Almost 86.06% of these were between 10 and 50 cm gbh (1630ha^{-1}), 4.75% (90 ha^{-1}) were ≥100cm gbh (figure-6). There were 16 recruits ha^{-1} and 42 death ha^{-1} (table-6). Average basal area of Yebone in 2011 February was 36.4 m^{-2}ha^{-1} (table-7). Small trees contribute 18.08% (6.58 m^{-2}ha^{-1}), medium-sized trees 18.08% (6.58 m^{-2}ha^{-1}), and large trees 63.85% (23.24 m^{-2}ha^{-1}) to the total basal area (figure-7). In 2012, 0.02 m^{-2}ha^{-1} were gained through recruits and 1.04 m^{-2}ha^{-1} were lost through death.

Table (6) Density (n tree ha^{-1}) in the main plot at 8-6 point, Kyauk-shut, and Yebone for different size classes

	8-6 point		Kyauk-shut		Yebone	
Size class (cm gbh)	2010	2012	2010	2012	2010	2012
all (≥10)	1484	1566	1736	1788	1894	1868
small (10-50)	1356	1428	1450	1492	1630	1604
medium (50-100)	94	104	208	210	174	176
large (≥100)	34	34	78	86	90	88
recruits		142		118		16
death (≥10)		60		66		42

Table (7) Basal area (m^{-2} ha^{-1}) in the main plot at 8-6 point, Kyauk-shut, and Yebone for different size classes

	8-6 point		Kyauk-shut		Yebone	
Size class (cm gbh)	2010	2012	2010	2012	2010	2012
all (≥10)	31.85	33.56	35.58	37.61	36.4	36.62
small (10-50)	7.03	7.49	6.15	6.55	6.58	6.64
medium (50-100)	3.52	4.02	8.38	8.48	6.58	6.55
large (≥100)	21.3	22.05	21.05	22.57	23.24	23.43
recruits		0.21		0.12		0.02
death (≥10)		0.8		0.4		1.04

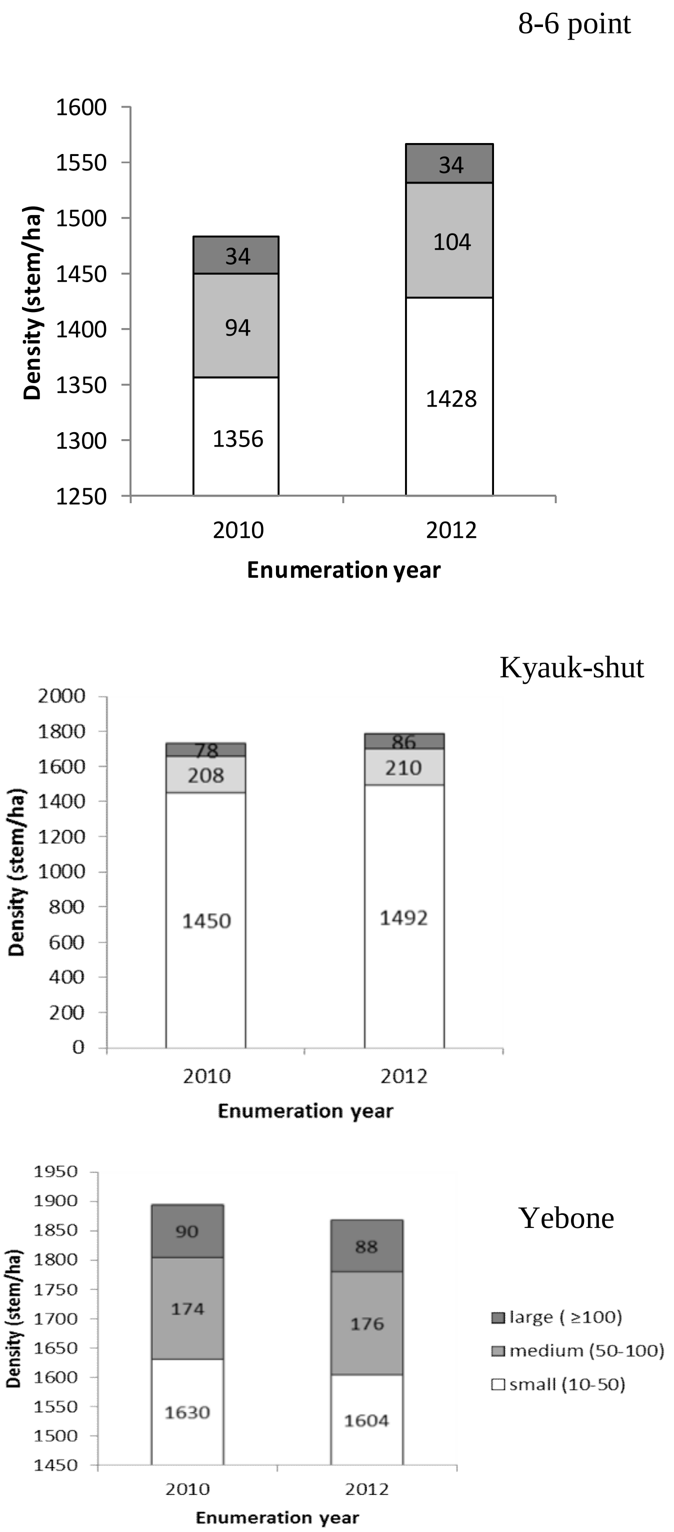


Figure (6) Change in density for 8-6 point, Kyauk-shut, and Yebone at the second enumeration. Proportion of small (white bars), medium-sized (Iright gray bars), and large trees (dark grey bars)

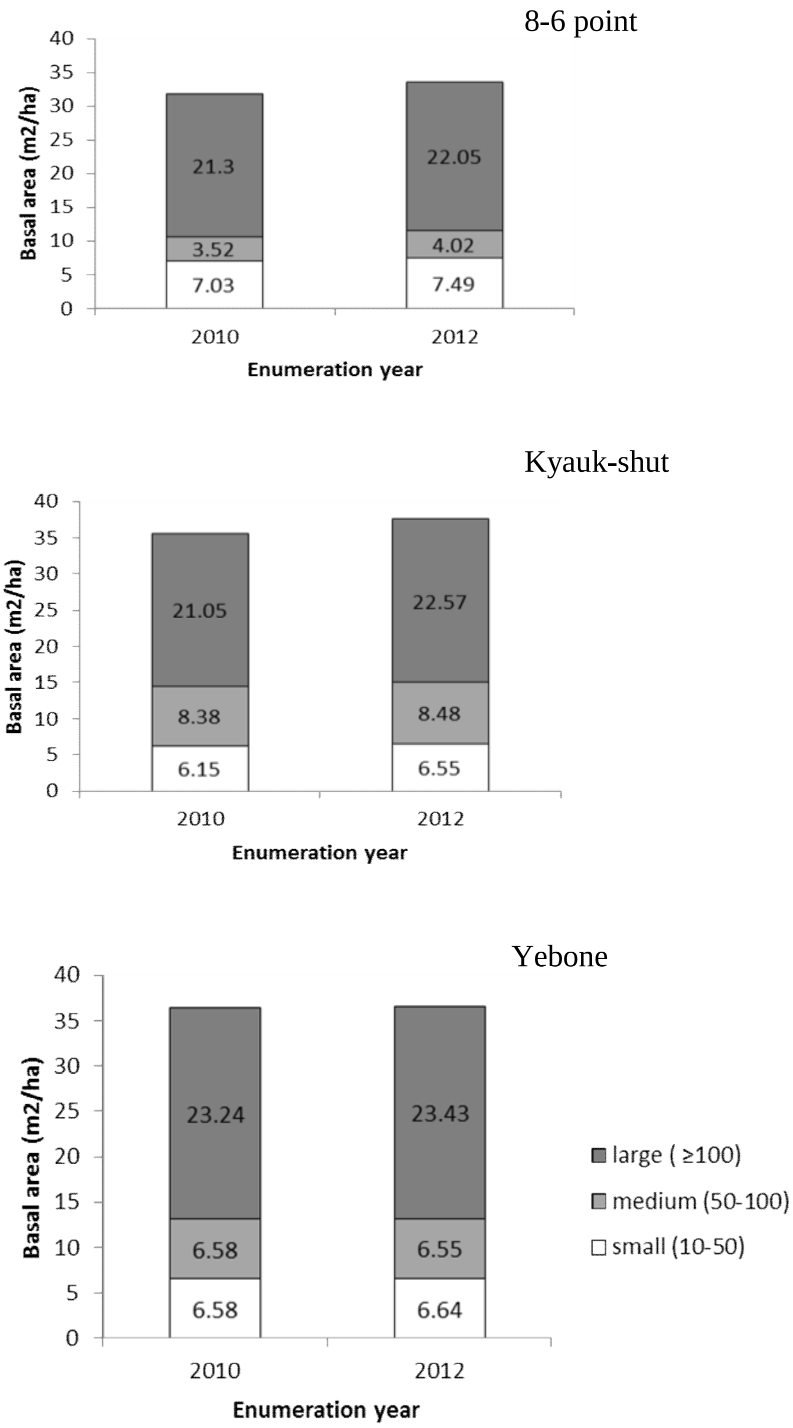


Figure (7) Change in basal area for 8-6 point, Kyauk-shut, and Yebone at the second enumeration. Proportions of small (white bars), medium-sized (Iright gray bars), and large trees (dark grey bars)

5.2 Floristic composition of three main plots in 2012

5.2.1 Floristic composition

The main plot at 8-6 point in 2012 consisted of 783 trees with a gbh ≥10cm, these being of 100 species in 59 genera and 32 families. Almost 38 of the species (38%) had <5 and over one quarter (26%) only one individual. Those species with > 5 individuals were 646 trees in 35 species (table-8).

The main plot at Kyauk-shut in 2012 consisted of 894 trees with a gbh ≥10cm, these being of 130 species in 79 genera and 38 families. Almost 43 of the species (33%) had <5 and 39 species (30%) only one individual. Those species with >5 individuals were 727 trees in 48 species (table-8).

The main plot at Kyauk-shut in 2012 consisted of 802 trees with a gbh ≥10cm, these being of 129 species in 70 genera and 37 families. Almost 48 of the species (37%) had <5 and 45 species (35%) only one individual. Those species with >36 individuals were 742 trees in 48 species (table-8).

The three main plots differed in their numbers of species: 8-6 point has least number of species and Kyauk-shut had highest number of species. With increasing size classes, the contribution of species with less than five or only one individual (frequency, f) became larger: while in the small tree size class 30.09% had ≥5 individuals and 26.60% just one tree, in the medium size tree 0% had ≥5 individuals and 39.29% had f=1, and in the large size class 0% had ≥5 individuals and 55.56% had only one tree in 8-6 point (table-8).

The small tree size class 35.09% had ≥5 individuals and 29.82% just one tree, in the medium size tree 6.82% had ≥5 individuals and 47.73% had f=1, and in the large size class 4% had ≥5 individuals and 72% had only one tree in Kyauk-shut (table-8).

The small tree size class 28.45% had ≥5 individuals and 41.38% just one tree, in the medium size tree 7.69% had ≥5 individuals and 81.54% had f=1, and in the large size class 0% had ≥5 individuals and 68.75% had only one tree in Yebone (table-8).

Table (8) Floristic composition of three main plots in 2012 in different size classes, including all species (f≥1) and showing the relative contribution of <5 and those with only one individual

I. all trees (gbh ≥ 10cm)	8-6 point	Kyauk-shut	Yebone
	f ≥ 1	f ≥ 1	f ≥ 1
families (n)	32	38	37
genera (n)	59	79	70
species (n)	100	130	129
trees (n)	783	894	934
trees (n ha^{-1})	1566	1788	1868
	n	n	n
species (f=1)	27 (27%)	39 (30%)	45 (35%)
species (f=2 - < 5)	38 (38%)	43 (33%)	48 (37%)
species (f>5)	35 (35%)	48 (37%)	36 (28%)
II. small tree (gbh 10- < 50cm)	8-6 point	Kyauk-shut	Yebone
families (n)	31	34	37
genera (n)	54	71	66
species (n)	94	114	116
trees (n)	714	746	802
trees (n ha^{-1})	1428	1492	1604
	n	n	n
species (f=1)	25 (26.60%)	34 (29.82%)	48 (41.38%)
species (f=2 to 5)	40 (42.55%)	40 (35.09%)	35 (30.17%)
species (f>5)	29 (30.09%)	40 (35.09%)	33 (28.45%)
III. medium trees (gbh 50- < 100cm)	8-6 point	Kyauk-shut	Yebone
families (n)	16	25	20
genera (n)	23	37	30
species (n)	28	44	39
trees (n)	52	105	88
trees (n ha^{-1})	104	210	176
	n	n	n
species (f=1)	11 (39.29%)	21 (47.73%)	24 (61.54%)
species (f=2 to 5)	17 (60.71%)	20 (45.45%)	12 (30.77%)
species (f>5)	-	3 (6.82%)	3 (7.69%)
IV. large trees (gbh ≥ 100cm)	8-6 point	Kyauk-shut	Yebone
families (n)	5	14	15
genera (n)	7	20	26
species (n)	9	25	32
trees (n)	17	43	44
trees (n ha^{-1})	34	86	88
	n	n	n
species (f=1)	5 (55.56%)	18 (72%)	22 (68.75%)
species (f=2 to 5)	4 (44.44%)	6 (24%)	10 (31.25%)
species (f>5)	-	1 (4%)	-

5.2.2 Tree diversity

The Meliaceae was the most abundant family in terms of tree numbers having had more than three times as many trees as second ranked family Euphorbiaceae in 8-6 point, the Euphorbiaceae was the most abundant family in terms of tree numbers having had more than two times as many trees as second ranked family Meliaceae in Kyauk-shut. The Meliaceae was the most abundant family in terms of tree numbers having had about two times as many trees as second ranked family Lauraceae in Yebone. Table 9 shows 5 most abundant families in three main plots. Of 59 genera, 6 were in Euphorbiaceae, 5 were in Lauraceae and Rubiaceae, 4 were in Meliaceae and Annonaceae in 8-6 point. Species and genera richness of families in 2012 were shown in table 10.

Table (9) Five most abundant families in 2012 in the three main plots with their numbers of trees (n) and percentage contribution to the total (%)

	8-6 point		Kyauk-shut		Yebone	
family	n	%	n	%	n	%
Meliaceae	261	35.18	51	5.88	264	27.88
Euphorbiaceae	85	11.46	108	12.44	88	9.29
Lauraceae	38	5.12	21	2.42	135	14.26
Rubiaceae	18	2.43	53	6.11	-	-
Annonaceae	42	5.66	23	2.65	51	5.39
Myrtaceae	-	-	-	-	65	6.86
others	298	40.16	612	70.51	344	36.33

Table (10) Five most abundant families with species and genera richness in 2012

	8-6 point		Kyauk-shut		Yebone	
family	species	genera	species	genera	species	genera
Meliaceae	13	4	9	4	14	5
Euphorbiaceae	11	6	9	7	16	8
Lauraceae	9	5	11	4	12	5
Rubiaceae	8	5	10	9		
Annonaceae	7	4	7	4	7	4
Myrtaceae					8	2

Although total number of individual increased steadily between the enumerations, neither Shannon's H' nor evenness changed notably for all trees (table 9). With increasing size classes, Shannon's index decreased and lowest for large trees ≥ 100cm gbh.

Among the three study sites, Kyauk-shut possesses highest diversity value within two enumeration (H'=6.14, 6.15), Yebone has second highest diversity value (H'= 5.59, 5.56), and 8-6 point stands least diversity value (H'=5.32, 5.27) for all size classes (table 11). Higher diversity value was occurred in second enumeration in Kyauk-shut but it was contrary in 8-6 point and Yebone, the first enumeration had higher diversity value than second enumeration.

Table (11) Diversity measures for the three main plots at two enumeration in different size classes, showing numbers of trees (n), species richness (S), diversity (Shannon index, H'), and evenness (E)

		8-6 point				Kyauk-shut				Yebone			
size class	year	n	S	H'	E	n	S	H'	E	n	S	H'	E
all	2010	742	102	5.32	0.8	868	128	6.14	0.88	947	130	5.59	0.8
	2012	783	100	5.27	0.79	894	130	6.15	0.88	934	129	5.56	0.79
small	2010	678	96	5.2	0.79	725	112	5.98	0.88	815	116	5.39	0.79
	2012	714	94	5.15	0.79	746	114	5.99	0.84	802	116	5.37	0.78
medium	2010	47	29	4.54	0.93	104	45	5.04	0.92	87	40	4.54	0.85
	2012	52	28	4.51	0.94	105	44	5	0.92	88	39	4.54	0.86
large	2010	17	9	2.97	0.94	39	21	4	0.91	45	33	4.88	0.97
	2012	17	9	2.97	0.94	43	25	4.26	0.92	44	32	4.87	0.97

5.3 Dynamics

5.3.1 Mortality and recruitment

Annual and periodic mortality rates for trees of ≥ 10cm gbh were: 8-6 point: 2.06% y^{-1}, 4.04%, Kyauk-shut: 2.04% y^{-1}, 3.80%, Yebone: 1.19% y^{-1}, 2.22%.

Annual and periodic recruitment rates for trees of ≥ 10cm gbh were: 8-6 point: 4.72% y^{-1}, 9.57%, Kyauk-shut: 3.56% y^{-1}, 6.80%, Yebone: 0.45% y^{-1}, 0.84%.

Annual and periodic recruitment rates were about two time higher than annual and periodic mortality rates in 8-6 point and Kyauk-shut. But annual and periodic recruitment rates were about two time lower than annual and periodic mortality rates in Yebone (table-12).

5.3.2 Mortality in size classes

Annualized and periodic mortality was calculated for three main size classes (small, medium, and large trees) and additionally the class of small trees was subdivided into 10 cm classes; this was not applied to medium and large trees, because tree numbers were low in these size classes (table 13). In 8-6 point and Kyauk-shut sample plots, m_a was highest for small sized trees (2.11% y^{-1} and 2.22% y^{-1}) and no mortality for large tree (figure 8-a,b), but it was contrary in Yebone: large trees had highest (3.6% y^{-1}) and medium trees had no mortality (figure 8-c). Within the small sized classes, 10-20cm, 20-30cm, and 30-40cm sized classes were higher m_a and 40-50cm size class had no mortality in 8-6 point and Kyauk-shut.

Table (12) Rate of mortality and recruitment in the three main plots at 2010 to 2012

	2010-2012		
	8-6 point	Kyauk-shut	Yebone
m_p (%)	4.04	3.80	2.22
m_a (% y^{-1})	2.06	2.04	1.19
r_p (%)	9.57	6.80	0.84
r_a (% y^{-1})	4.72	3.56	0.45

m_p, m_a: periodic and annual mortality

r_p, r_a: periodic and annual recruitment

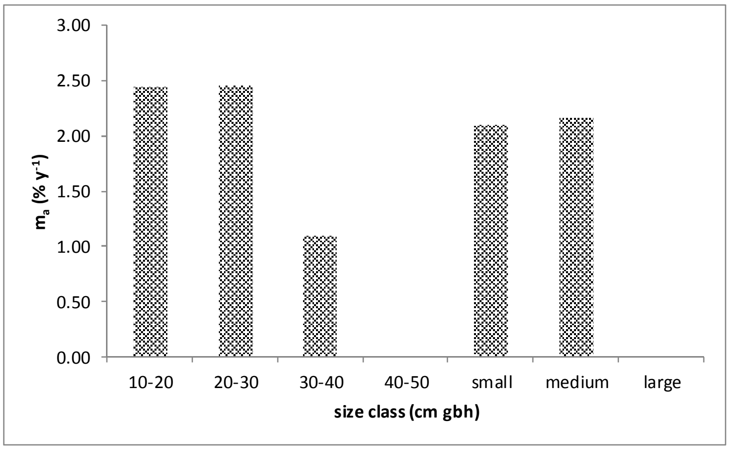
Table (13) Number of trees and mortality rate in size classes during 2010 to 2012

	8-6 point				Kyauk-shut				Yebone			
Size class	n_{10}	n_{d12}	m_p (%)	m_a (%y^{-1})	n_{10}	n_{d12}	m_p (%)	m_a (%y^{-1})	n_{10}	n_{d12}	m_p (%)	m_a (%y^{-1})
10-20	375	18	4.80	2.45	469	20	4.26	2.29	553	12	2.22	1.19
20-30	166	8	4.82	2.46	132	7	5.30	2.86	121	2	1.68	0.9
30-40	92	2	2.17	1.10	65	3	4.62	2.48	89	3	3.49	1.87
40-50	45	-	-	-	59	-	-	-	52	1	1.96	1.05
small	678	28	4.13	2.11	725	30	4.14	2.22	815	18	2.26	1.21
medium	47	2	4.26	2.17	104	3	2.88	1.54	87	-	-	-
large	17	-	-	-	39	-	-	-	45	3	6.67	3.6

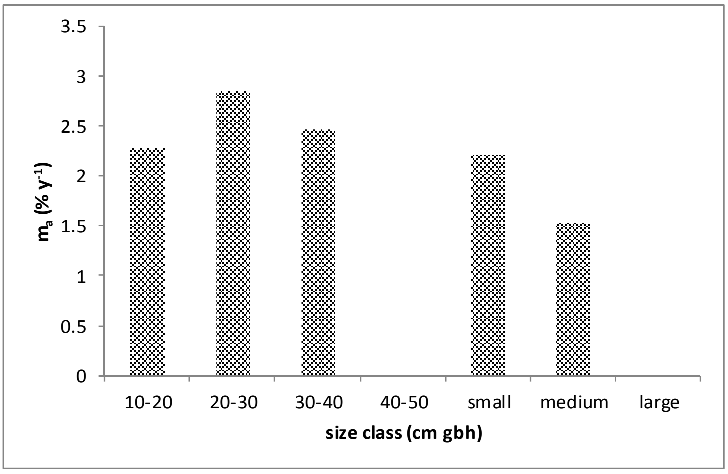
n_{10}: number of tree at 2010, n_{d12}: number of death at 2012

m_p, m_a: periodic and annual mortality

(a)



(b)



(c)

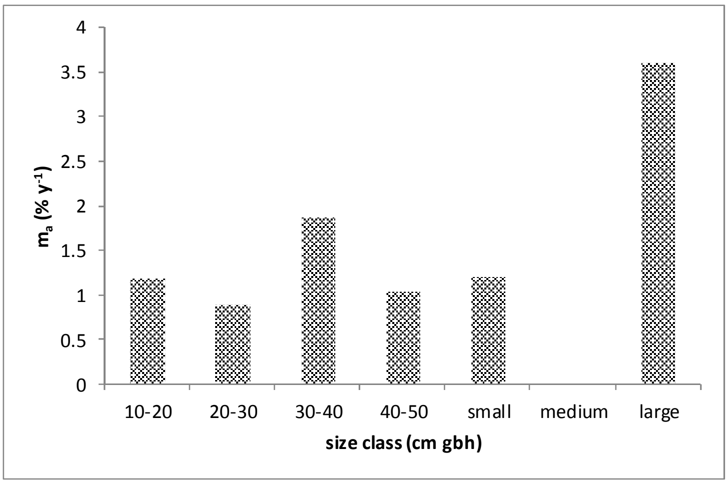


Figure (8) Mortality rates within size classes at three main plots (a) 8-6 point, (b) Kyauk-shut, (c) Yebone.

5.3.3 Mortality within families

In 8-6 point, family Meliaceae has highest numbers of individual in 2010 enumeration (n_{10}= 261), about 3.7% was death tree in 2012 (n_{d12}= 8); the annual mortality was 1.56 % y^{-1} table 14. The family Rubiaceae has 18 individual in 2010 enumeration (n_{10}= 18), about 11.11% was death tree in 2012 (n_{d12}= 2). The annual mortality rate was 5.78 % y^{-1} table 14. The family Meliaceae was highest numbers of individuals in all sample plots but the mortality rate was lower than other family (figure- 9). So that mortality rate is not related with numbers of individuals. The mortality rate was highest in Rubiaceae and Lauraceae (5.78 % y^{-1}, 5.46 % y^{-1}) in 8-6 point, Lauraceae and Annonaceae (10.63 % y^{-1}, 2.34 % y^{-1}) in Kyauk-shut, and Lauraceae and Euphorbiaceae (2.39 % y^{-1}, 1.22% y^{-1}) in Yebone.

Table (14) Mortality rate (m_a; % y^{-1}) for families of the most abundant species

	8-6 point			Kyauk-shut			Yebone		
family	n_{10}	n_{d12}	m_a	n_{10}	n_{d12}	m_a	n_{10}	n_{d12}	m_a
Meliaceae	261	8	1.56	51	2	2.11	264	1	0.20
Euphorbiaceae	85	1	0.60	108	1	0.49	88	2	1.22
Lauraceae	38	4	5.46	21	4	10.63	135	6	2.39
Rubiaceae	18	2	5.78	53	0	0	-	-	-
Annonaceae	42	2	2.43	23	1	2.34	51	1	1.05
Myrtaceae	-	-		-	-	-	65	1	0.82

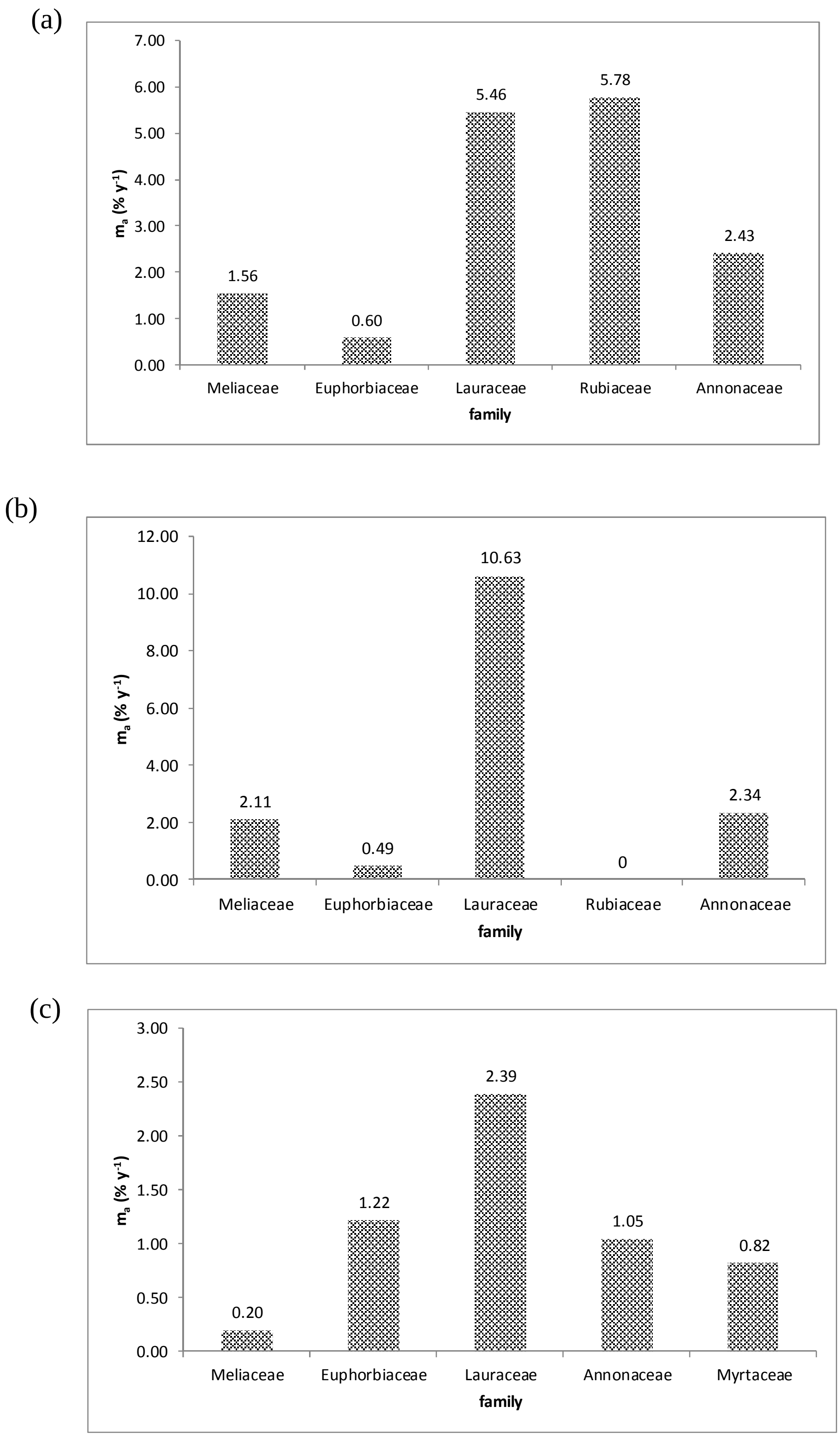


Figure (9) Mortality rates within family of the most abundant species at three main plots (a) 8-6 point, (b) Kyauk-shut, (c) Yebone.

5.4 Growth

5.4.1 Negative growth rates

After the exclusion of unreliable gbh measurements at second enumeration, the calculation of agr produced 684, 819, and 904 individuals in 8-6 point, Kyauk-shut, and Yebone respectively. Of these, 7 plants (*c.* 1%) had negative growth rate in 8-6 point. They are *Chisocheton* sp.: -5.05 mm y^{-1}, -5.05 mm y^{-1}, -5.05 mm y^{-1}, *Aglaia argentea*: -12.62 mm y^{-1}, *Actinodaphene* sp (1): -10.10 mm y^{-1}, *Myristica angustifolia*:-10.1 mmy^{-1}, *Aglaia* sp: -5.05 mm y^{-1}. These may be due to slightly faulty measurements in first enumeration or natural shrinkage of bark or loss of bark in measuring point. Other two plots had no negative result.

5.4.2 Growth across three main plots

With the 684 valid trees in 8-6 point between 2010- 2012, mean absolute growth rate was 9.62 mm y^{-1} and mean relative growth rate was 22.25 mm m^{-1} y^{-1}. In Kyauk-shut, 819 valid trees and mean absolute growth rate was 10.54 mm y^{-1} and mean relative growth rate was 22.10 mm m^{-1} y^{-1}. In Yebone, 904 valid trees with mean absolute growth rate was 5.33 mm y^{-1} and mean relative growth rate was 15.47 mm m^{-1} y^{-1} (table-15).

Table (15) Comparison of growth rates at three main plots: numbers of valid trees and absolute (agr; mm y^{-1}) and relative (rgr; mm m^{-1} y^{-1}) growth rates

	n	agr	rgr
8-6 point	684	9.62	22.25
Kyauk-shut	819	10.54	22.10
Yebone	904	5.33	15.47

6. Discussion and conclusion

Almost 783 trees these being 100 species representing 59 genera, 32 families in 8.6 point, 894 trees these being 130 tree species, 79 genera, 38 families in Kyauk-shut, and 934 trees these being 129 tree species, 70 genera, 37 families in Yebone were examined in 2012 enumeration. A total of 2611 trees in total area of 1.5 ha were visited in 2012. The stem density and basal area of tree in 2012 December was 1566ha^{-1} and 33.56 m^{-2} ha^{-1}in 8-6 point, 1736 ha^{-1}and 37.61 m^{-2} ha^{-1} in Kyauk-shut, and 1894ha^{-}1 and 36.62 m^{-2} ha^{-1}in Yebone respectively. The stem density and basal area of primary lowland dipterocarp forest in Danum Valley, Malaysia was 2078ha^{-1} and 32.5m^{-2}ha^{-1}(Newbery N.M., 2005). Though stem density in TNR forest is fewer, basal area was higher than primary lowland dipterocarp forest in Danum Valley, Malaysia.

Most abundant families in terms of numbers of trees in the TNR forest are Meliaceae, Euphorbiaceae, Lauraceae, Annonaceae, Rubiaceae and Myrtaceae. All these families are included in the most abundant families of Danum Valley, Malaysia.

Annualized and periodic mortality was calculated for all trees (≥ 10 cm gbh), for size classes and for families. For size class calculation, three main size classes (small, medium, and large trees) were divided and additionally the class of small trees was subdivided into 10 cm classes. The annual mortality rate (m_a) of all trees (≥ 10 cm gbh) in TNR forest are 2.06% y^{-1}, 2.04 % y^{-1}, 1.19 % y^{-1} in 8-6 point, Kyauk-shut and Yebone respectively. Which are not too much different with Danum Valley (m_a 1.59 % y^{-1} to 2.30% y^{-1}). Most of the death trees in sample plots were due to falling of old trees into small trees, and making large nest and feeding on wood by termites. Human disturbances like illegal cutting, fire wood collection have never seen in sample plots. Generally the small sized classes, 10-20cm, 20-30cm, and 30-40cm sized classes were higher mortality rate than other size classes. This pattern was not seen in Danum Valley, where mortality was highest for medium sized and lowest for large trees in period 1 and in the second period, mortality increased with increasing sized because of the drought effect (Newbery N.M., 2005). As a family wise mortality rate, Lauraceae was higher mortality rate than other families (5.46% y^{-1}, 10.63 % y^{-1}, 2.39 % y^{-1} in 8-6 point, Kyauk-shut and Yebone). This family had also high mortality rate in Danum valley (2.21% y^{-1}, 4.02 % y^{-1}).

Annualized and periodic recruitment was calculated for all trees (≥ 10 cm gbh). The rate of recruitment was about two times higher than mortality rate. Although the numbers of recruited trees were higher than the dead trees, the diversity index in 2012 slightly high. An explanation of this lies in the strong dominance by few species, as a result of which the numerical influence of the recruitment of new species was low.

Mean absolute growth rate was 9.62 mm y^{-1}, 10.54 mm y^{-1}, 5.33 mm y^{-1} in 8-6 point, Kyauk-shut and Yebone respectively. The growth rate of primary lowland dipterocarp forest in Danum Valley, Malaysia was 3.33 mm y^{-1} one stand and 2.90 mm y^{-1} in other.

(Newbery N.M., 2005). The growth rate in TNR forest was 2 to 3 times higher than Danum Valley.

In the present investigation, the floristic composition, diversity, mortality rate, recruitment rate, and growth rate of the forest stand were understand and this information can support how to approach forest ecosystem management and conservation within framework of Tanintharyi Nature Reserved Forest management; and provide a broad overview of management systems in tropical rain forest of Myanmar. Rainforest is a potentially renewable resource with the resilient ability to recover from disturbance, through regeneration, succession and recovery processes, if there are no significant changes in the abiotic environment and sufficient and proximate seed sources remain. The renewable characteristic is thus obvious, but its sustainability depends on the management applied to the forest (Favrichon 1998). The planning for management based on scientific and ecological research in Myanmar is very limited and need to develop. The recent research can partially fulfill the information of Tanintharyi Nature Reserved, identify the species composition, and clarify ecology of forest dynamics of Tanintharyi Nature Reserved Forest.

7. Recommendation

The present dynamics research was very short term study (December 2010 to December 2012) so that natural dynamics process could not be clear. Long term study (*c.* 10-15 years) should be implemented to make clear the dynamism of TNR forest.

To comprehend the natural regeneration, some of the subplots should be studied more detail, such as all seedlings and saplings should be counted, measured height and basal diameter, mapped their position and calculate for their growth, mortality and recruitment.

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