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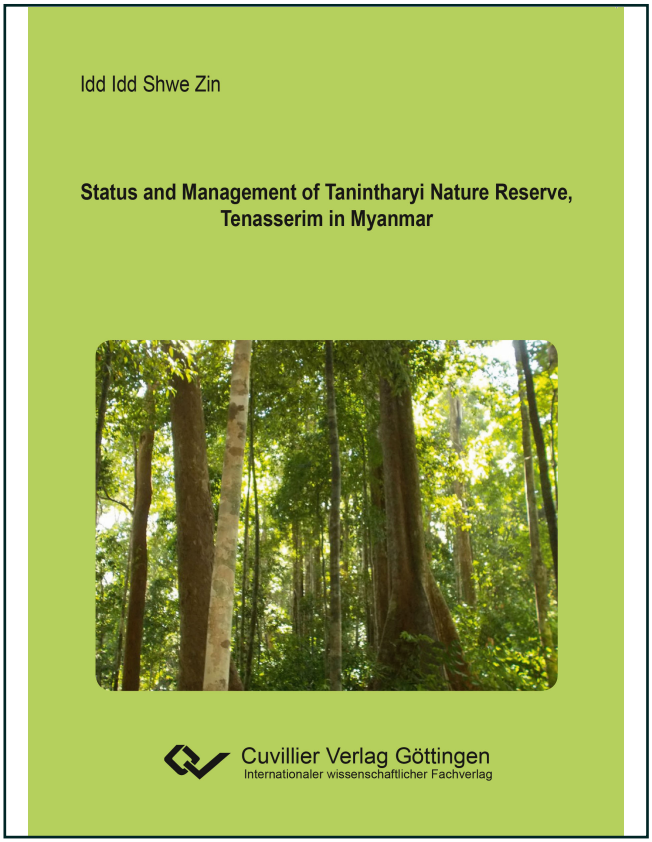
# Status and Management of Tanintharyi Nature Reserve, Tenasserim in Myanmar

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# 1 Introduction

## 1.1 Background information

In many tropical countries, land conversion of natural forest into agricultural land has been on the increase in recent decades (Miller, 1993; Landa et al., 1997), not only impacting the natural environment but also affecting the lives of local people (Lal, 1977; Chonghuan and Lixian, 1992; Miller, 1993; Landa et al., 1997). Given the increase in human population growth and the growing economic development in both developing and developed countries, the human impact on the environment will be large and further deteriorate already fragile ecosystems (Vitousek et al., 1997). The impacts of these changes have already begun and include the loss of biodiversity and degradation of land, which in turn has resulted in many economic, social, and cultural losses.

Protected areas (PAs) provide tangible solutions to the problems of both species loss and adaptation to climate change (Hannah et al., 2002). The UNEP World Conservation Monitoring Centre found a rate of 3% tropical forest losses from 2000 to 2005 in protected areas in the countries studied, considerably less than in the surrounding, unprotected areas (Campbell et al., 2008). Biodiversity and other positive traits, characteristics, and products of a healthy ecosystem continue to be lost (Butchart et al., 2010); as a result, protected areas are a powerful means by which to address biodiversity loss, help buffer society from the effects of climate change, and maintain the critical ecosystem services upon which all societies depend (Lopoukhine et al., 2012).

The expansion of protected areas is a good indicator of environmental performance (CBD, 2010); for this reason, increasing attention is turned to protected area management, as it is one of the key aspects needed for the effective conservation of PAs. Protected area systems have become more numerous in the past 25 years, particularly in developing countries where biodiversity is rich. Concurrently, the mission to conserve biodiversity in protected areas has improved human social development (Naughton-Treves et al., 2005). In Myanmar, greater attention has been focused on sustainably developing protected areas. According to the Forest Department (FD), national parks, nature reserves, and wildlife sanctuaries were as of 2009 regarded as protected areas in line with the “Protection of Wildlife and Wild Plants and Conservation

of Natural Areas Law" (1994) which regulates the establishment of seven Myanma categories of PAS, which in turn can be compared with the six IUCN categories (1994, as cited by Dudley, 2008).

Myanmar is a developing country and local people depend on extracted natural resources from adjacent forests for survival; as a result, they do not give due regard to sustainability under the current circumstances. Today, many people are facing the difficulties that come along with unsustainable management, unequal distribution of resources, corruption, and natural calamities that make their livelihoods vulnerable. Illegal logging, shifting cultivation practices, expansion of agriculture lands, industry pollution, and population growth are all causing severe environment and ecosystem degradation (FD, 2016). One effect of this is the loss of biodiversity in both natural forests and protected areas, sometimes to the point of species extinction.

In Myanmar, the management strategies of the PA system have been reviewed in order to better address gaps in the coverage of globally threatened species, natural habitats, key biodiversity areas, and wildlife corridors (Istituto Oikos 2011). The best solution for managing PAs has changed with a territorial model design for zoning that is connected through biodiversity-oriented, managed landscapes (Mata et al., 2009; Rodríguez-Rodríguez, 2012). Today, the creation and management of a buffer zone with sustainable development activities has begun in Myanmar in order to 1) prevent the degradation of the last patches of forest, and 2) effectively conserve protected area via local development.

### 1.2 The significance of biodiversity and forest management system in Myanmar

Myanmar is one of largest countries in mainland Southeast Asia with an area of 676,577 $km^2$ (MOECAF 2011). According to the Forest Resource Assessment conducted in 2015, 42.9% of the country's total area is still covered with forests. In Myanmar, there are eight different categories of major forest ecosystems due to the complex river system and the great variation in rainfall, temperature, soil type, topography, and relative distance to the sea (MOECAF 2011); of the forest types, the montane and lowland evergreen forests possess the most species richness (MOECAF 2011). Myanmar also possesses numerous endemic wild flora and fauna, as well as about 300 species of mammals, about 300 species of reptiles, and over 1000 species

of both birds and butterflies (FD, 2016). According to Davis et al., (1995), cited by MOECAF (2011), the International Union for Conservation of Nature identified plant diversity at four geographical points in Myanmar. These include Northern Myanmar (with an estimated 6,000 species), Tanintharyi (with an estimated 3,000 species), Natmataung National Park and the Chin Hills (with an estimated 2,500 species), and the Bago Yoma Range (with an estimated 2,000 species).

Due to a growing population and high timber demand from neighboring countries, natural forests have been declining in both quantity and quality. In order to maintain the stable environment in the country, the Myanmar Selection System (MSS) has been applied since 1856; this involves the formation of felling series, each of which is divided into 30 similarly sized annual coupes based on equal productivity that are worked over a 30-year felling cycle. In this system, exploitable tree sizes are harvested with limitations on girth to not only sustain timber production yields, but also to ensure the many ecological functions required to support the habitats of flora and fauna. It is essential that forest management planning in the protected areas is regularly revised and the forest inventory promoted by providing sufficient resources to recognize the MSS as a sound management system in the evergreen forest. It is also necessary to check the growing stocks in each girth class. Because Tanintharyi Nature Reserve (TNR) is so remote and it locates in region characterised by conflicts and political instability so that it is difficult to both accurately select trees for harvesting and enumerate future yields in the buffer zone forest areas. It is necessary to make adjustments with current forest resources for sustainable forest management in the evergreen forests as well as in protected areas.

### 1.3 Major threats to Biodiversity

In Myanmar, the major threats to biodiversity are improper land use (e.g., upland shifting cultivation, clear cutting of natural forests for agricultural expansion), overexploitation of natural resources, illegal logging and trade, over-abstraction of groundwater, and uncontrolled pesticide and herbicide use (MOECAF, 2014). Due to the ever-increasing demand for resources from neighboring countries, Myanmar's biodiversity is under severe pressure that could result in habitat degradation and forest loss (Aung et al., 2004). The root causes of biodiversity loss are poverty, economic growth, lack of comprehensive land-use policies/planning, lack of environmental

safeguards, limited grassroots support for conservation, and global climate change. In addition, the participation of local communities in the conservation and sustainable use of Myanmar's natural resources is essential in order to effectively protect the country's biodiversity.

Moreover, unsustainable and unreported illegal exploitation has forced many wildlife species to extinction; indeed, illegal hunting occurs in nearly 70% of protected areas (Rao et al., 2002). Much of the illegal activity in protected areas also exploits plants on a commercial scale; in addition, the impacts of logging have been documented on the forests (Brunner et al., 1998). Myanmar possesses great diversity in plant species, but many commercial tree species, including *Tectona grandis*, *Pterocarpus macrocarpus, Xylia xylocarpa,* and the family Dipterocarpaceae are overexploited for commercial logging. According to Global FRA (2015), Myanmar has lost more than 546,000 hectares of forest on average each year since 2010 due to the over-exploitation of forest resources, deforestation, forest degradation, and the loss of forest habitats; this threatens the biodiversity of the terrestrial forest ecosystems.

### 1.4 Protected Areas and Forest Protected Areas

Protected areas are the cornerstones for all national and regional biodiversity conservation strategies (Dudley, 2008); as such, they have become a key indicator of environmental conservation (Dudley, 2008). PAs have been established in Myanmar to conserve biodiversity and maintain diverse, representative ecosystems (MOECAF 2011). They may be defined as an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity and natural/cultural resources; they are managed through legal or other effective means according to the IUCN (1994, cited in Dudley, 2008). Not only do PAs fulfill the basic needs of the local people, they also maintain local heritage and stabilize the environment (Dudley and Phillips, 2006).

There are six management categories for protected areas based on primary management objectives, ranging from strictly protected nature reserves to multiple-use areas in accordance with the IUCN protected area management categories (IUCN, 1994, cited by Dudley, 2008). They are:

Ia: area managed mainly for science or wilderness protection;
Ib: area managed mainly for wilderness protection;

II: area managed mainly for ecosystem protection and recreation;
III: area managed mainly for the conservation of specific natural features;
IV: area managed mainly for conservation through management intervention;
V: area managed mainly for landscape/seascape conservation or recreation;
VI: area managed mainly for the sustainable use of natural resources.

Some of these IUCN categories may consist entirely of forests, contain part of a forest, or even have no forest at all. They needed to define Forest Protected Areas as a separate "element," not only for management purposes, but also to assess/report resources, institute regional criteria, process indicators, and improve public awareness and participation (IUCN, 1994, as cited by Dudley and Phillips, 2006). A Forest Protected Area is "a subset of all protected areas that includes a substantial amount of forest and it may be the whole or a part of a protected area" (IUCN, 1994, as cited by Dudley and Phillips, 2006). Furthermore, many forested areas make up either a) corridors between the protected areas to permit species to move between them, or b) buffer zones that form an extra layer of protection around the core zone to conserve biodiversity (Dudley and Phillips, 2006) and other activities which improve the socio-economic condition of the surrounding communities (Bhusal 2014). According to Dudley and Phillips (2006), they sometimes act as "stepping stones," or more isolated areas in the natural habitat that provide flag stops for migrating or mobile species that have difficulty crossing large, inhospitable areas. These corridors, stepping stones, and buffer zones are integral parts of many protection strategies but often have no official protected area. Moreover, the "biological corridor," "conservation corridor," "ecological stepping stone," and "buffer zone" are processes of management practices or landscape functions; as such, they do not automatically confer protected status for conservation in such areas through limited and voluntary conservation agreements. Instead, permanent commitment is required (Dudley and Phillips, 2006).

In Myanmar, conservation of natural resources has been in practice for many years. The first protected area was established in 1918, while conservation activities began with the Nature Conservation National Park Project (NCNPP) created under the joint implementation of the UNDP and the Myanma government between 1981 and 1984. The Nature and Wildlife Conservation Division (NWCD) under the direct management of the Forest Department (FD) is responsible for nature conservation and PAs (Myint Aung 2007). Myanmar has established PAs to conserve biodiversity and maintain

diverse, representative ecosystems (FD 2009). According to a 2009 national report on biodiversity, the protected area coverage increased from 26,214 $km^2$ to 37,932 $km^2$ (from 2009 to 2013). Including proposed parks, 5.6 % of Myanmar's total area is protected, which is well within the relevant policy target. Myanmar's PAs include the sub-temperate forests in the north and mangrove and tropical rainforests in the south. All forest lands are owned by the state; nevertheless, private and communal tenure systems also exist (FAO 2001).

According to the FD (2016), Reserved Forests (RFs), Protected Public Forests (PPFs), and Protected Areas (PAs) constitute a Permanent Forest Estate (PFE) in Myanmar. The country's goal is to have 30% of its total area as RF and PPF and 10% as PAS; currently, RF and PPF constitute 24.72% of Myanmar's total area (FD, 2016). By 2016, 39 protected areas covering 5.75% of the country's total area had already been established (FD, 2016). Among the PAs, two Ramsar Sites—Moeyungyi Inn Wetland Wildlife Sanctuary (2004) and Indawgyi Lake Wetland Wildlife Sanctuary (2016)—have been approved by the Ramsar Convention. In addition, Inlay Lake was established by the UNESCO MAB-ICC in June 2015 as a biosphere reserve, the first in Myanmar.

The protected area system falls under the "Protection of Wildlife and Wild Plants and Conservation of Natural Areas Law" (1994), which replaced the old "Wildlife Protection Act" of 1936. This law regulates the establishment of seven categories of PAs (nature reserve, scientific nature reserve, national park, marine national park, wildlife sanctuary, geo-physically significant reserve) and other nature reserves as determined by the Minister of the Ministry of Natural Resources and Environmental Conservation (MONREC).

Tropical evergreen forests, especially evergreen dipterocarp forests, occur in the southern part of Myanmar. Tanintharyi Nature Reserve (TNR) was established in 2005 as a protected area (TNRMP 2009) where tropical moist evergreen forests are dominant. Shifting cultivation, illegal logging, and the establishment of estate-crop plantations (rubber, traditional orchards, oil palm, etc.) are the major issues facing TNR; deforestation is therefore one of the most serious threats to wildlife and natural resources here. As a result, the FD and agencies like Motamma Gas Transportation Company (MGTC) and Tanintharyi Pipeline Company (TPC) support the planning, establishment, and operation of tropical rainforests and their biodiversity in TNR. For

effective conservation of TNR areas, a useful model for TNR's zoning management reserve has been in practice since 2009, where a core zone area is surrounded by a buffer zone and a transition corridor (TNRMP 2009).

### 1.5 Zoning management inTanintharyi Nature Reserve

In Myanmar, the changing political and economic conditions are encouraging of the greater private sector's investment in hydropower, agro-industry, and other industries with potentially large environmental footprints. The level of investment in conservation is relatively low, and many sites face severe threats. There is undoubtedly a need for the establishment of different strategies regarding certain specific investment priorities. Currently in Myanmar, the critical nature in conserved areas has been turned into protected areas for the conservation of biodiversity**.** Here, local participation in protected area management is not given much attention due to poor technical knowledge, lack of active participation, and weak site-based management plans for the systematic zone management of the nature reserve. Moreover, customary rights needed to be recognized in Myanmar, and a buffer zone should be put under the close management of the local community. National or regional success in protecting a landscape depends not only on government support and management organizations, but also on the active involvement of the local community (Rao et al., 2003).

TNR was designed as a systematic zoning management project (Project Document TNR 2001) in accordance with the classification of Myanmar's protected areas (Category [d] Nature Reserve); in this system, seven PA categories of zoning systems reflect intended land use, existing patterns of land use, the degree of human use desired, and the level of management and development required (FD 2009). According to Zin (2009), most areas in this reserve were regarded as a core zone with the aim of maintaining conditions and checking for the loss of habitats and biodiversity; the remainder was considered a buffer zone systematically managed in order to balance the immediate needs of local communities and the long-term goals of biodiversity. This buffer zone can also be managed in order to protect the core zone and rehabilitate degraded areas. According to Li et al., (1999), a buffer zone protecting a core zone is not only a major link between reserve managers and the local people, it is a key basis for the biological conservation and development of the reserve.

## 1.6 Development of a buffer zone in Tanintharyi Nature Reserve

The concept of a buffer zone was developed by UNESCO to create an additional thin layer of protection around a protected area as a pathway for development of local communities (Aryal, 2008). Two definitions for buffer zones are proposed: the first is “areas peripheral to a national park or equivalent reserve, where restrictions are placed upon resource use or special development measures are undertaken to enhance the conservation values of the area" (Sayer, 1991); the second is "areas adjacent to protected areas, on which land use is partially restricted to give an added layer of protection to the protected area itself while providing valued benefits to neighbouring rural communities" (MacKinnon as cited in Wells & Brandon, 1993, p.159). Activities in the buffer zone are allowed so as to help protect the core area. In many biosphere reserves, the buffer zone is regarded as an area in which human use is less intensive than what might be found in the transition zone (UNESCO, 2003); it is additionally an area in which to manage natural vegetation, agricultural land, forests, fisheries, or ranchland with the goal of enhancing overall quality of production while conserving natural processes and biodiversity. This zone may also accommodate education, training, tourism, and recreation facilities.

According to Zin (2009), buffer zones may be located either inside or outside the legal boundaries of protected areas. Their functions are either physical (for wildlife) or social (for local communities). In the former, the habitat spaces of wildlife are extended within the protected areas, allowing larger populations of plant and animal species within the reserve; in the latter, local communities receive limited use of the natural resources within the zone to meet their basic needs. The main objective of the establishment of buffer zones is to provide for the basic needs of local communities on a sustainable basis. The buffer zones should therefore be accessible and large enough to meet the local people’s requirements for land, grazing areas, forest products, meat, or cash (Zin, 2009). According to MacKinnon (1986), the buffer zone should not be a thin linear strip following the boundaries of the protected area.

There are many different types of buffer zones for protected areas, including traditional use zones in the protected area, forest buffers, economic buffers, and physical buffers. Traditional Use Zones are designated in cases where no suitable land exists outside the reserve; instead, part of the reserve is available to the local people to provide them

with forest products, e.g., fishing (without poison or explosives), traditional hunting of non-protected species, honey, fruit, firewood, rattan, and some grazing of domestic animals, so long as it does not conflict with the grazing of their wild counterparts (Zin, 2009).

Economic buffers are needed in order to reduce instances of the locals taking resources from the reserve itself; they may include cash crops, wildlife hunting permits for use outside the reserve, or even a share of the income from the reserve. Forest buffers support firewood needs or timber forests outside the protected area boundaries; they may be natural forests, secondary forests, or even plantations which support the local population with maximum yield while maintaining good soil and water protection. In the buffer zone areas, plantation forests are one of the most applied resource management concepts for the sustainable conservation of protected areas. Where there are no available lands to act as a buffer, physical buffers like fences, ditches, and canals can serve to discourage wildlife from leaving the reserve as well as people and domestic animals from entering.

Buffer zones, a core zone, and a transportation corridor have been designated for the effective management of TNR according to TNRMP (2009). The land cover in the northern and southern parts of TNR was deforested and degraded in the core zone due to shifting cultivation, village encroachment, and mining activities (Mon, 2012); furthermore, in the northern part of the buffer zone, many natural forests have been converted into ever-increasing numbers of rubber and palm oil plantations. Meanwhile the cultivated areas, including lands used for agriculture and horticulture, were expanding and encroaching on forest lands due to the increasing population. Within and around TNR, closed forest areas (including moist evergreen and semi-evergreen forests) decreased due to disturbances like shifting cultivation or conversion to rubber plantations; meanwhile, bamboo areas in TNR and neighboring areas increased.

### 1.7 Problem Statement

In Myanmar, major threats to the forests include improper and ineffective land use for the cultivation of agricultural crops, shifting cultivation, encroachment into forests, and indiscriminate cutting of forests in the nature reserves and national parks. When forest areas are modified for other land use, forest ecosystems across the country are

devastated, which consequently threatens the conservation of biodiversity. Since 2010, forests have lost 546000 hectares (1.7% of the forest area), and all the biodiversity therein, annually (Global Forest Resources Assessment, 2015). Deforestation is occurring at an alarming rate due to logging (legal/illegal) and taung-ya cutting (shifting cultivation). However, it is important to keep in mind that deforestation in Myanmar can be the result of not only man-made activities, but also natural disasters. In order to rehabilitate the degraded land areas and conserve the rest of the forests, quantitative data and knowledge of the present state of the forest in each forest type should be inventoried.

Protected areas have traditionally been in the form of national parks, which required drawing a fixed boundary around an area and focusing management efforts within that area. Now, many established protected areas (including nature reserves) involve focusing management efforts outward from a boundary by incorporating core conservation areas and protective buffer zones that serve to limit negative impacts to the core while also allowing for sustainable resource utilization (Hales, 1989; Castro et al., 1995; Miller, 1996). All three zone cases involved in the Man and the Biosphere (MAB) model by the United Nations Educational, Scientific and Cultural Organization (UNESCO) demarcated a core protected area surrounded by zones, allowing for a greater intensity of use (Rotich 2012). The buffer zone concept was modified by UNESCO for the protection of the core zone, the rehabilitation of degraded areas, and the provision of material, cultural, and spiritual benefits to local residents on a sustainable basis (Bajracharya 2009). Another goal of the buffer zones is to incorporate the needs of local people into the management process so as to gain their support (Wells and Brandon 1993).

In recent years, buffer zones have played an increasingly important role in the operational approach to nature conservation; as such, they are seen as important tools in conserving areas of ecological importance while simultaneously addressing the sustainable development of the rural poor living in the area (Ebregt and Greve, 2000). In Myanmar, the buffer zone management concept is intended to assist national parks and reserves in the sustainable protection and conservation of natural resources; however, there is limited information on instituting effective, uninterrupted, and community-based forest management systems with the local people in the buffer zone. In addition, development activities in the buffer zones of protected areas are limited

and sufficient data and information to make right decision regarding buffer zone management and conservation in Myanmar is lacking. Today, buffer zone management concepts have been widely accepted; their two objectives are to improve the management of natural resources and conserve ecological conditions in the buffer zone areas in order to create an extended habitat for wildlife (Dhakal and Thapa 2015).

Similarly lacking is detailed information on 1) vegetation, 2) the major threats in management zones, and 3) the social and economic benefits they provide in the development of local communities. Management policies towards buffer zone management are also still required, particularly in floristic composition, natural regeneration, stand structure, and stand dynamics; also lacking are the prerequisites for the sustainable management of the remaining tropical forests in the buffer zones of protected areas. Specific information on plant community structure and the floristic composition of primary and secondary moist evergreen forests is still needed in order to support guidelines for their management and conservation, understand stand dynamics, and assess the maintenance potential of plant species diversity in Southern Myanmar (Tenasserim), particularly in TNR.

In Myanmar, tropical evergreen forests possess the highest species richness with regards available high-value timber (MOECAF 2011). The major threats in TNR are shifting cultivation, illegal logging, extension of seed orchards, and forest fires. The dry and moist deciduous forests mostly occur below 150 m of the TNR (Smith, 1926). In the working plans of the Heinze/Kalienaung Reserve (1926-27 to 1935-36), most of forests below this elevation 150 m were subjected to *taungya* (shifting cultivation) (Smith, 1926). Consequently, the quality and biodiversity of natural forests areas are continuing to decrease and changing into degraded forests which are characterized by low volume and wood quality in the TNR buffer zone areas. In TNR areas, there are major challenges to restore biodiversity in the core zone and recover over a large area in the degraded forests in the buffer zone.

Reforestation and/ or afforestation are the most promising approaches for rehabilitation techniques in the degraded lands. Moreover, the higher amounts of clay content in soil composition are distinctly recorded in the degraded forest lands (Sections 4.4.1 and 5.6), especially in TNR low land forests. Salt or clay content in the soil could be increased with soil depth (Isbell 1962); its effect can change the relationship between

soil water potential and water content due to arising anomalous' effects of salt through the clay content and it produces an osmotic effect that contributes to total soil water potential and it is related with plant growth (Tunstall 2005). Salt stress is obviously one of limiting factors for plant growth in the degraded lands which are subjected to natural and anthropogenic stresses in the TNR buffer zone areas. In order to counteract the rate of deforestation, reforestation is one option for rapid recovering the degraded lands, but limited information on the ecology of indigenous species (dominant and pre-dominant trees) and their adaptation to the environmental and salt (clay) stresses could be assessed in three forest types of the TNR buffer zones. Moreover, while the plant water potential indicates the immediate water supply available for root-uptake, the plant osmotic potentials (midday and saturated) can be used as a function of seasonal plant growth and site adaptation (Mitlöhner, 1997) for the reforestation program; these are very important tools for determining the relationship between trees and the environment. The selection of species and sites, as well as the monitoring of tree species adaptation, are very important for the implementation of a buffer zone for agroforestry and community forestry in order to sustain the remaining forests and rehabilitate the degraded land areas in TNR.

However forest degradation has an effect on soils, their fertility, productivity and overall quality and loss of SOC reduced water holding capacity (Dlamini et al., 2014). In the degraded forests, *Xylia xylocarpa* trees are one of the dominant species; their growth are very fluted and twisted, and its bark doesn't look as healthy due to the excessive moisture in the air and these forests are only a few kilometers from the Andaman Sea (Smith, 1926). It is one of popular commercial tree species because of its properties; it can be used as an ecological indicator at low land areas of TNR buffer zone. The ability of native species to withstand to salt stress or clay soil content should be carefully examined for environmental stability, biodiversity and long term needs of local people. Although *Xylia xylocarpa* trees show their ability to grow well in high temperatures in natural stands (Phukittayacamee et al., 1993) and tolerate potentially damaging heat stress (Saelim, 1977) in TNR degraded areas; it is essential to assess their response to the maximum stress of soil salinity to a certain extent via the measurements of plants' internal potentials or ecophysiological measurements (i.e. plant osmotic potentials).

In TNR, there is lacking information regarding topical tree species' response to light intensity; no research has been done on classifying tree species into different levels of

light requirements to understand about forest dynamics. Changes in the light gradient were determined by differences in forest structure, especially in presence of shade tolerant and intolerant species (Niinemets et al., 1998). Moreover, it is quite difficult to understand the tree species' characters for selection of species in reforestaion program, TNR bufferzone degraded areas. Nitrogen plays an important role in tropical forests by influencing and limiting plant growth, survival, and regeneration distribution (Cole and Rapp, 1981; Evans, 2001; Dawson et al., 2002; Javasingam and Vivekanantharaja, 1994, Pham, 2012). Tropical tree species respond to different light intensity, which growth parameters and microelements in woody tissues can be used to classify tropical tree species into light-requirement groups in quantitative ways in TNR natural forests. Therefore, the identification of a stable isotope and its relation to species' light requirements; nitrogen isotope (atomic $\delta$15N or total N) values, and top heights were added in order to examine their relationship to the light requirement characteristics of tree species in these tropical forests of TNR and support the reforestation program in the degraded land areas of TNR buffer zone areas.

This study furthermore provides important information for the planning process of management systems such as harvesting or thinning and enumeration of future yield in the buffer zone forests. Moreover, it supports in the recommendation of sound silvicultural practices in forest restoration and rehabilitation procedures as well as in the provision of critical data for conservation activities. In this study, furthermore, light intensity (nitrogen content % or top height), osmotic potentials (salt stress) in the root zone, and wood density (drought resistance or hydraulic safety) are important factors affecting the biomass, photosynthesis and growth for selection of tree species in the rehabilitation program of TNR bufferzone degraded land areas. In Myanmar, limited studies have focused on the interaction of the three factors (water content or hydralulic abilities, salt stress or clay content and light requirement groups) in moist evergreen and moist deciduous forests in the TNR.

## 1.8 Objectives

This study was conducted to enhance and support efforts to sustainably manage the forests in Tanintharyi Nature Reserve, Myanmar. The specific objectives are as follows:

- Examine the current status of species composition, species diversity, stand structure, and natural regeneration in the moist evergreen and degraded moist deciduous forests in the core and buffer zone areas of TNR.

- Investigate the species-site matching of dominant and pre-dominant native tree species in order to determine their adaptability in terms of ecophysiology measurements, e.g., plant osmotic potentials.

- Evaluate the salinity adaptation of *Xylia xylocarpa* (from the moist deciduous forests) by applying NaCl salt solution and determine the effect of land degradation on that adaptation.

- Determine the characteristics of moist evergreen and moist deciduous forest tree species via: the determination of whether or not these relationships can be used to classify studied trees into three light-requirement groups by assessment of $\delta$15N, total N values (% MS) and top height for selection of tree species in the reforestation program in TNR natural forests.

- Assess a possible relationship between the stem diameter distributions and wood density in the sapwood tissues of tree species within particular sites.

- Analyze the relationship of minimum midday and minimum saturated leaf osmotic potentials and the stem diameter distributions of tree species for soil osmotic stress in their root zone.

- Propose recommendations/suggestions for management strategies regarding tree species selection for reforestation and rehabilitation in the TNR buffer zone forests.

# 2 Description of study site

## 2.1 Location of Tanintharyi Nature Reserve (TNR)

The study area lies in the townships of Yebyu and Dewai, Dewai District in the northern part of the Tanintharyi Division in Myanmar. It is situated between the Dawei River and Myanmar-Thailand border in Southern Myanmar. The TNR area (Figure 2.1) is located between the latitudes 14° 20' 50" and 14° 57' 55" North and between the longitudes 98° 5' 10" and 98° 31' 32" East (Anon, RS & GIS, FD, 2007). TNR was designated as a nature reserve under Protected Area System (PAS) in 2005 with a total area of 1700 square kilometers (170,000 ha). It consists of three reserves: the eastern parts of Kaleinaung Reserve and Heinze Reserve (about 85,725 ha) as well as Luwaing Reserve (about 84,273 ha) (TNRMP, 2013). These reserves, which consist of old tropical rainforests, were classified as Reserve Forests in 1885, 1902, and 1932 respectively (Thein, 2007).

## 2.2 Topography

The area is characterized by undulating terrain and high elevation ranging from 15 m above sea level in the lowlands to 1,400 m at the ridge of the Thai border; the latter area has a slope of more than 37% (Anon, RS & GIS, FD, 2007). The mountain range here runs from north to south while the slope rises from west to east, climbing to the top of the ridge. Most sample plots of primary moist evergreen forest-1 in the core zone and primary moist evergreen forest-2 and secondary moist evergreen forest in the buffer zone are located in the middle slope of the mountain range; most sample plots of degraded moist deciduous forest-1 in the core zone and degraded moist deciduous forest-2 in the buffer zone are in the lowlands at altitudes ranging from 65-671 m. From a conservation of biodiversity perspective, TNR lies within "Biounit 5d (Uga, 2006), and the Tenasserim-South Thailand semi-evergreen moist forest region. The area has been identified by WWF as one of the world’s threatened terrestrial ecosystems as it is connected to Thailand’s Western Forest Complex and is of significance as a trans-border protected area in Asia.