

**Ministry of Natural Resources and Environmental Conservation**

**Forest Department**

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**RS and GIS Section**

**Assessment on Land Use and Land Cover Status of Tanintharyi Nature Reserve Area  
and its Surrounding**

**September, 2019**

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# **Assessment on Land Use and Land Cover Status of Tanintharyi Nature Reserve Area and its Surrounding**

## **Executive Summary**

Land use and land cover change is a major force of ecological change in the tropical regions. The pattern and process of deforestation and forest degradation have thus received considerable attention in ecological, socioeconomic, and policy studies to support effective management. Realizing the need to provide information, Remote Sensing and GIS section of Forest Department conducted monitoring on major land use and land cover types of Tanintharyi nature reserve-TNR area periodically using various satellite images. By comparing major land use and cover of TNR between 2006 and 2015 separately in three areas; TNR area, 10km outside area of TNR and surrounding of TNR area, the results revealed that although forest cover was quite stable within TNR area, decreasing of forest cover areas was resulted within 10km outside area of TNR and its surrounding areas.

## 1. Introduction

Although tropical rainforests covered around 5% of world land surface, they are rich, exclusive biodiversity and most complex ecosystem on the earth. It was estimated that as many as 30 million species of plants and animals live in tropical rain forests. They are also critical in the global carbon cycle, climate system and home to about half of the world's species and provide a livelihood for millions of people (Olander et al., 2008). The conservation and protection of tropical forests has thus received worldwide attention. However, an expanding human population and associated demands for goods and services continue to exert increasing pressure on the ecological systems of tropical forests (Etter et al., 2006). Land use/land cover change, particularly that of tropical deforestation and forest degradation, has been occurring at an unprecedented rate and scale throughout the world. Deforestation and forest degradation of tropical rain forests is continuous and rapid conversion of primeval forest to other land uses. For the purpose of ecosystem and biodiversity conservation of these forests, it is necessary to examine the characteristics of these changes in land use (Ishikawa, 2007).

One-fifth of total annual carbon emissions were from land-use change, most of which involves tropical deforestation (Kannin et al, 2007). Land use, land-use change and forestry (LULUCF) activities are a major source of carbon emissions and active contributors to global warming. The Intergovernmental Panel on Climate Change (IPCC) estimates that 1.6 billion tons of carbon is released annually due to land-use change, of which the major part is traced to tropical deforestation. However, accurate and up-to-date information is still very limited in tropical developing countries. Time series analysis of land use/land cover change and the identification of the driving forces responsible for these changes are needed for the sustainable management of natural resources and also for projecting future land cover trajectories (Giri et al., 2003).

Myanmar is endowed with a highest percentage of forest cover in the Asia Pacific region; forests cover is 42.92% of the total land area of 676,000 km<sup>2</sup> at 2015 (FRA 2015). Moreover, forest ecosystems vary widely in terms of species composition, productivity and production due to an extensive network of natural waterways, mountain ranges of varying altitudes that reach a maximum of 6,000 m in the north, and wide geographic spread of its land mass. Myanmar is therefore relatively rich in forest resources that represent a globally unique biodiversity resource (Leimgruber et al., 2005). For recent years, Myanmar forests face high pressure from increasing demands of forest products and growing population. Forest cover assessment using satellite images showed that forest cover of Myanmar decreased from 57.96

% of the total land area of the country in 1990 to 51.53% in 2000, 49.24% in 2005, 46.96% in 2010 and 42.92% in 2015 (FRA 2015).

Forest management in Myanmar is being focused on sustainability of forest resources; such as sustainable production of goods and services for local needs and export, and conservation of its ecosystem and environment. Myanmar forest policy 1995 focused on sustainable forest management and intended to improve areas of permanent forest estate including reserved forests, protected public forests, and protected area system. In case of protected areas system, the goal is to extend the coverage of the PAS to 10% of total land areas of Myanmar. Among the being established and proposed PASs, Tanintharyi Nature Reserve project (TNRP) is also an important one for practicing biodiversity conservation.

Monitoring of land use and land cover by remote sensing plays a major role to understand how historical and current land use and land cover status. As mention before, land use and land cover change is a major force of ecological change in tropical regions. The pattern and process of deforestation and forest degradation have thus received considerable attention in ecological, socio-economic, and policy studies to support effective management mechanisms. A better understanding about the dynamics of LULC is essential. This aids in knowing the drastic and abrupt changes along with unpredictable consequences to monitor local and global climatic and environmental changes (Worku and Elmar, 2015) as well as biodiversity. Realizing the need to provide information on the present status of major land cover types of the region and identify major land use and cover change areas ('hot spots') for TNR, monitoring of land use and land cover of in and around TNR areas was done in order to provide information for management. According to the development of technics and satellite data sources, i.e. space technology is advanced day by day, various data sources were applied in TNR land cover assessment. Although assessment of land use and land cover was conducted using Landsat images in 1990 and 2006, ALOS images in 2010, Spot 7 images in 2015 and Worldview-2 2016 were applied regarding to provide updated more and more information for management mechanisms. In this report, land use and land cover of 2016 was estimated by Worldview-2 images. And comparison of land use and land cover changes during the periods from 1990 to 2006, from 2006 to 2015 and from 2015 to 2016 using same resolution images.

## **2. Background Information**

TNR lies in southern Myanmar and within Biounit 5d, i.e. one of the global biodiversity conservation units. It also falls within Tenasserim-South Thailand semi-evergreen moist forest region which is nationally important, regionally significant and globally outstanding region in

southern Myanmar. Accordingly, TNR was established by Ministry of Environmental Conservation and Forestry (MOECAF), formerly Ministry of Forestry (MOF), on the 30<sup>th</sup> of March 2005 to conserve tropical rainforests and their constituent biodiversity and to contribute sustainable livelihood of local communities by getting involved in conservation works.

Although forest is associated with mixed deciduous and bamboo forest in the lowlands of TNR, there is almost tropical rain forest in high elevation mountain sites. There are 258 species of flora including 5 critically endangered and 5 endangered species in TNR. In case of fauna, 67 Mammal species and 244 bird species are recorded.

Land use and land cover status TNR were assessed using Remote Sensing and GIS in order to contribute the effective management activities. Satellite images of 1990, 2000, 2006, 2010, 2015 were used to understand the trend of land use and land cover changes not only for TNR area but also within 10km outside of TNR boundary and surrounding areas of TNR (outside of TNR). Based on previous results, land use and land cover changes were quite significant over time inside TNR and in the vicinity of TNR. Most of them might be due to human impacts such as encroachment and illegal village settlements, shifting cultivation, Subsistence hunting and logging, illegal logging and Small-scale tin mining etc.... Land use and Land cover status of 1990 and 2015 were shown in Table 1.

Within and around TNR, closed forest including closed evergreen and closed semi-evergreen forest were decreased. On the other hands, open forest including open evergreen and open semi-evergreen forest were increased. Due to some disturbances like vast areas of bamboo brakes, bamboo representing areas were increasing in TNR and its neighbouring areas. Cultivated areas including agriculture lands and horticulture were also increasing and this might be due to increasing population and encroachment into forest lands. Similarly, areas of rubber and oil palm plantations were also increasing in this region.

### **3. Objectives**

The main objective was to provide information for implementing effective management for long term existence of TNRP and its biodiversity richness. To achieve this objective, we conducted the following activities using RS and GIS:

- (1) Producing 2016 land use/land cover map of TNR area
- (2) Comparison on land use/land cover in different periods; i.e. from 1990 to 2006, from 2006 to 2015, from 2015 to 2016

Table 1: Land use and Land cover status of TNR and its surrounding in 1990 and 2015 based on Landsat Images

No	Land use and Land cover categories	Area (ha)					
		TNR Area		10 km Buffer of TNR		Surrounding TNRP	
		1990	2015	1990	2015	1990	2015
1	Closed Forest	132,822.12	96661.46	58,245.19	1118.12	46361.12	26558.96
2	Open Forest	18,578.47	33827.82	9,586.38	30741.44	17,202.61	40174.59
3	Water body	336.47	413.04	1,229.93	1118.12	25,287.12	26558.96
4	Agriculture Land	788.92	618.79	11,093.37	4531.11	22,335.02	16992.61
5	Mangrove Forest			1.70		7237.57	8599.17
6	Grass Land	227.51	4286.67	2,187.16	11423.46	1,513.72	16170.47
7	Dry Grass				2691.15		367.47
8	Sand		41.82	1.96	138.36	684.32	1188.00
9	Young Rubber	162.25	70.99	1,012.10	7848.26	274.81	4134.29
10	Bamboo	5,120.06	9438.83	4,615.93	6716.67	1,200.79	5684.28
11	Scrub Land	11,915.62	24117.37	63,739.26	60136.69	45,708.83	33125.42
12	Horticulture Land	47.59	2.18	3,482.04	2417.21	3,241.35	858.98
13	Others		433.46		921.58		1401.27
14	Oil Palm			2.73	1493.59	0.18	707.22
15	Shifting cultivation		37.42		1364.34		504.52
16	Old Rubber		49.14		3692.69		5316.12
		169999.00	169999.00	155196.03	155196.03	171047.45	171047.45

Notes: Closed forest represents evergreen forest (closed), semi-evergreen forest (closed).

Open forest represents evergreen forest (open), semi-evergreen forest (open)

## 4. Materials and Methods

### 4.1. Study Area

TNRP area is situated at the Dawei District, between the Dawei River and the Myanmar-Thailand border, Taninthayi Region, consists of the eastern part of Heinze-Kaleinaung Reserve Forest and Luwein Reserve Forest. Geographically, it is approximately situated between latitudes 14°20'50" and 14°57'55" North, and between longitudes 98°5'10" and 98°31'32" East. This area encompasses approximately 1,700 km<sup>2</sup> or 169,999 hectares (Appendix I and II).

The Project area is covered plenty of mountainous range and there are little plain areas near the riverine and coastal line which is out of TNR area. Most of the mountain range is running from north to south. The area is located in a tropical monsoon type of climate zone, but since it lies only round about 14 degree north of the equator, the dry season here is much shorter and total annual rainfall is greater than in the rest of the country. Dawei District has an average rainfall of over 5400 mm with about 145 rainy days and with a mean humidity of around 64-88%. Average temperature is 25°-28°C, with the highest temperatures reaching

34.3°C in March, while the lowest temperatures can drop to 18°C around January (Dawei District Forest Management Plan).

## 4.2. Data Sources

In this assessment, high resolution Worldview-2 images were applied in order to compare with previous year assessment. Previously, high resolution Spot 7 satellite images with 5 m spatial resolution of Blue, Green, Red, Near Infrared and 1.6 m spatial resolution of Pan Chromatic were applied after Pan-sharpening process. This assessment applied Worldview-2 images (2.5 meter resolution) that were acquired on 17- 11-2016 covered around 90% of the TNR area. Other images acquired on 03- 03-2017 were covered around 10% of TNR.

The following table shows the type of images that were used in previous assessment of TNR and its surroundings.

Table 2: Summary of data sources used for previous and current land use and land cover assessment of TNR

Acquisition Dates and Years	Satellite/Sensor	Spatial Resolution (meter)
1990	Landsat 5 TM	30
2006	Landsat 5 TM	30
5-12-2009 and 26-02-2010	ALOS	10
5-02-2015	Landsat 8 OLI & TIRS	30
20-01-2015	Spot 7	5
18- 11-2016 (90% of TNR)	Worldview-2 image	2.5
17- 03-2017 (10% of TNR)		

## 4.3. Satellite Image Classification by 2016 Worldview-2

A supervised image classification was used in assessment of land use/land cover of TNR in 2016. The basic steps, such as training stage, feature selection, selection of appropriate classification algorithm, post classification smoothing and accuracy assessment were involved in the classification procedure. In training area selection, Worldview-2 image were applied with false color composite with band combination of Red (band 4), Green (band 3) and Blue (band 2) in order to obtain effective land use/land cover classification. Training areas were selected by visual interpretation of false color composite images. We assigned training areas that were groups with homogeneous characteristics and also the representative of corresponding land use/ land cover categories. Different land use/land cover categories in the



images were discriminated using image classification algorithms using spectral features, i.e. brightness and colour information contained in each pixel.

Ground verification records and previous digital land use/land cover maps were also used during the selection of training areas in order to obtain the greatest accuracy of the classification results. Training areas representing the homogeneous spectral characteristics of the defined land use/ land cover categories, i.e., 11 of land cover categories related to TNRP area were selected to perform supervised classification. More than thirty training samples for each category were created visually by Area of Interests based on the homogeneity of the reflectance pixel values. Maximum Likelihood Classification was conducted by using the selected training samples in the analysis of multi-spectral image data. Land use and land cover of TNR was finally categorized into seven major classes including, forest (closed), forest (open), other wooded land (bamboo dominant areas, scrub land, grass land), agriculture lands (cultivated lands, home garden and Horticulture), waterbody, others (buildup areas, sand etc) and plantation (rubber and oil palm) (Table 3).

Table 3: Re-categorized land use and land cover classes in image classification

No.	Land use/land cover categories	Re-categorized into major land use/land cover categories (for change detection)
1	evergreen (closed)	Closed forest
2	evergreen (open)	Open forest
3	mangrove	Closed forest
4	bamboo	Open forest
5	agriculture land	Cultivated land
6	Perennial Crops, Home garden, Horticulture Land	
7	dry grass	Other wooded land
8	Grass land	
9	scrub land	
10	shifting cultivation (practiced many years ago) and under fallow periods	
11	oil palm	Plantation
12	old rubber plantation	
13	Young rubber plantation	

14	Others (urban, village, settlements, road, built-up areas)	others
15	sand	
16	waterbody	waterbody

#### 4.4. Definitions used in assessment of land use and land cover

**Forest:** Land with tree crown cover (or equivalent stocking level) of more than 10 % and area of more than 0.5 hectares (ha). The tree should be able to reach a minimum height of 5 meters (m) at maturity *in situ*. May consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground; or open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10 percent.

**Closed Forests:** Formations where trees in the various stories and the under growth cover a high proportion (> 40 percent) of the ground and do not have a continuous dense grass layer.

**Open Forests:** Formations with discontinuous tree layer but with coverage of at least 10 percent and less than 40 percent. Generally there is a continuous grass layer allowing grazing and spreading of fires. This can be loosely called degraded forest.

**Other Wooded Land:** Land either with a crown cover (or equivalent stocking level) of 5-10 percent of trees able to reach a height of 5 meters at maturity *in situ*; or a crown cover (or equivalent stocking level) of more than 10 percent of trees not able to reach a height of 5 meters at maturity *in situ* (e.g. dwarf or stunted trees); or with shrub or bush cover of more than 10 percent.

**Other land:** Land not classified as forest or other wooded land as defined above. It is included agricultural land, meadows and pastures, built-up areas, barren land, etc.

##### 4.4.1. Brief description on characteristics of Land use and land cover

Before categorizing land use and land cover of TNR, vegetation types were also checked by three times field survey. The vegetation type information was used from Myanmar Standard Forest Types and Field Survey. The cover types include Evergreen Forest (Closed), Evergreen Forest (Open), Semi-evergreen Forest, Forest Plantation, Bamboo, Grass Land, Scrub Land, Horticulture/Home garden Land, Rubber Plantation, Oil palm and Agriculture Land, etc... .

Brief descriptions of major vegetation types, i.e. evergreen and semi-evergreen forest and land use and land cover categories mentioned in this report and their reflectance characteristics are as follows;

**Evergreen Forest (Closed):** It is Evergreen Forest where the crown density of tall trees is more than 60%. It is also the same as Giant Evergreen Forest of Myanmar Standard Forest Types and also called Tropical Rain Forest or Evergreen Dipterocarp Forest. These predominate in localities where rainfall exceeds 120 inches (3048 mm). Within the rainfall range of 60 inches (1524mm) to 120 inches, they also occur in shady valleys and places with a moist cool aspect. It is typical of South East Asia. Characteristic bamboos are *wanwe* or *waba* (*Oxytenanthera nigrociliata*). These forests provide a number of species of commercial importance amongst which are *Kanyin-byu* and *Kanyin-ni* (*Dipterocarpus alatus* and *turbinatus*), *thingan* (*Hopea odorata*), *Kaunghmu* or *thingadu* (*Parashorea stellata*), *kamaung* or *pyinma* (*Lagerstroemia speciosa*), *thitka* (*Pentace burmanica*), *shitle* or *taunghayet* (*Swintonia floribunda*) and *baing* (*Tetrameles nudiflora*). That is deep red colour on the imagery. The colour is change to deep purple in some deep slope areas, especially eastern side of Hnankye village areas.

**Evergreen Forest (Open):** Same as above mentioned type except that the forests included considerable open-space. Image colour of this area is more reddish or vermilion.

**Semi Evergreen Forest:** It is intermediate between Tropical Evergreen and the Moist Deciduous Forests. Evergreen and deciduous dominants occur usually mixed fairly intimately though local patches of almost pure dominants may occur. The lower storey is mainly evergreen and bamboos are usually present. The common species are *Pyinkado* (*Xylia dolabriformis*) and *Kanyin* (*D. turbinatus*). Other species are *Myaukchaw* (*Homalium tomentosum*), *Yemane* (*Gmelina arborea*), *Gyo* (*Scheichera trijuga*), *Lagerstroemia* species and *Bambwe* (*Careya arborea*). *Kyathaung* (*Bambusa polymorpha*) is the most common bamboo. *Waphyu* (*Dendrocalamus membranaceus*) and *Tin* (*Cephalostachyun pergracile*) are frequently found together. The reflectance characteristics of such forest is almost the same with evergreen forest (open), but a little bit turn to pink colour.

**Bamboo dominant forest** or Bamboo Forest: It was assumed that the areas where Evergreen Forest lost their wilderness and retrogressively succeeded by Bamboo Forest. Pure Bamboo breaks have been normally classified as Bamboo Forest but sometimes small trees are growing together. This vegetation was also assumed as open forest area in this study. Bamboo forests are distinctly yellowish orange colour on the imagery.

**Grass Land:** Grass Lands are mostly consequent of repeated shifting cultivation or forest cuttings. This land are mostly affected by repeated forest fire and some are rocky

mountains with shallow and poor soil effect. Such land cover represents as bluish green and yellowish white mosaics on the imagery.

**Scrub Land:** It means open land with scatter trees of coppice types whereas scrub forest will be degraded forest land comprised of small trees, which have been cut over and over for fuel wood. Scrub lands are whitish blue and yellowish brown mosaics on the imagery.

**Perennial Crops, Horticulture Land:** It means especially cashew plantations, betel nut plantations and other edible tree orchard areas. They are mostly situated along the road side and village surrounding. Most of these areas are reddish violet colour, purple and yellowish brown on the satellite imagery.

**Rubber Plantation:** Most of these are government owned plantations. It can be found along the road side. Rubber plantations are commonly pink and brown mosaics on the imagery.

**Oil palm:** These can be found on the way from Kaleinaung village to Yephyu town. They appear purple and brown mosaics, but sometimes it is difficult to define its colour.

**Agriculture Land:** This is normal agriculture land with annually cultivation. For normal agriculture, it is white colour, where black colour at irrigated areas, agriculture crops (red colour) and nearly harvest crops (green colour).

**Shifting Cultivation:** Areas under shifting cultivation practices and fallow lands are classified as shifting cultivation. Fallow lands are similar with scrub land due to growing of scrub and young forest trees. They are whitish blue and yellowish brown, and some areas with crops are pink mosaics on the imagery.

**Sand:** It meant that the areas with Sand, especially at the banks and beds of rivers and streams. They are white and pale color on the false color composite image.

**Bare land:** Areas characterized by bare rock and gravel with no vegetation present. They are white and pale color on the false color composite image and defined based on the location.

#### **4.5. Accuracy Assessment**

For accuracy assessment, GPS points were obtained by three times field survey conducted during February, March and May 2015. Additionally, spatial references were also collected from Google Earth images and totally 123 references were used for accuracy assessment. Classification error matrix was conducted by seven land use and land cover of

TNR; i.e. closed forest, open forest, other wooded land, agriculture lands, waterbody, plantation and others.

#### 4.6. Change assessment

Actual change can be obtained by a direct comparison between classification results of one date with the other date. Temporal condition of land covers that have occurred between the two dates were measured by performing a change matrix. In this report, change assessment was conducted as follows:

- by the Periods between 1990-2006 and 2006-2015 using previous assessment results
- Although there is different spatial resolution of 2015 (previous assessment results) and 2016 (current assessment), change detection was conducted in order to understand how effects of data sources.

After checking the accuracy of the 2016 classified image, classification error matrix was established using ground verification records (field survey and Google Earth), two land cover thematic maps; i.e. 2006 and 2010 were exported and overlaid in ArcGIS 9.3 to detect the forest cover changes of the study area (Dorren et al, 2003; Thapa and Murayama, 2009). Due to different land use and land cover categories in two year assessment, change detection was conducted using seven major land use and land cover categories after checking their accuracy.

#### 4.7. Deforestation analysis

Definitions and rules used to calculate deforestation and forest degradation are explained in Table 4. In calculating annual rate of net deforestation (%) and that of forest degradation, we followed the international research papers.

Table 4: Definitions and rules used to calculate deforestation and forest degradation

Change types	Definition and calculation of changes
Deforestation	complete conversion of forest to non-forest, i.e., closed and open forest to non-forests
Annual rate of net deforestation (%)	$\frac{\text{net deforestation}}{\text{total forest areas at initial year of assessment}} \times \frac{1}{\text{assessment periods}} \times 100$

## 5. Results

### 5.1. Accuracy assessment for classified land use and land cover

#### 5.1.1. Accuracy assessment of Worldview-2 Image Classification

Accuracy assessment was conducted after grouping the major land use and land cover categories. The error matrix of reference and classified land use and land cover categories shows the accuracy of the land use and land cover classification, i.e., 99 of 123 observations were correctly classified with an overall accuracy of 80.49 % and a kappa coefficient of 0.77. Table 4 presents accuracy information of land use and land cover categories by procedure's and user's accuracies. Producer's accuracies represent how well the classification was done, and user's accuracies which represent the confidence of the user of the map prepared by the classifiers. User's accuracies were low in closed forest, grass land and others categories, i.e. user's accuracy of 71.88%, 68.42% and 77.78% respectively when producer's accuracies were 79.31%, 100% and 100% respectively. The producer's accuracy of open forest is also about 54.54% (Table 4).

Table 4: Error Matrix of reference and classified land use and land cover categories

references	Classified								User's accuracy
	1	2	3	4	5	6	7	Total	
1	23	0	7	1	1	0	0	32	71.88
2	1	17	0	0	0	0	0	17	100
3	2	0	12	1	1	0	0	15	80.00
4		0	0	13	3	0	0	19	68.42
5	3	0	2	0	18	0	0	22	81.82
6		0	1	0	1	7	0	9	77.78
7		0	0	0	0	0	9	9	100
Total	29	22	24	17	15	7	9	123	
Producer's accuracy	79.31	54.54	75	100	86.67	100	100		

Overall accuracy= 80.49%

Kappa Statistics= 0.766

Notes: 1- closed forest, 2- open forest, 3- other wooded land, 4-grass land, 5-others, 6-settlement and 7-waterbody

### 5.2. Land use and Land cover of TNR area in 2015 and 2016

Table 6 represents the land use and land covert status of three assessed areas of TNR area in 2015 and 2016. Among 7 categories (combined categories), forest area, evergreen and semi-evergreen types was one of the dominant land cover in TNR and it covered over 78% of the

total area of TNR in 2016, i.e. closed forest 48.12% (81795.86 ha) and open forest 30.77% (52309.50 ha). Second larger cover was other wooded land, i.e. 18.60% of TNR (31612.87 ha). Due to the higher spatial resolution of worldview image used for 2016 than that of Spot image used for 2015, it seems that more forest cover is detected by remote sensing and also more clear indication on other land categories. Although the changing of using RS sources might be effecting on the image interpretation and it is recommended that not to compare directly between 2015 and 2016 land use and land cover due to its different data sources, we did change matrix in order to understand effects of data sources.

**Table 6: Land use and Land cover of TNR in 2015 based on Spot and in 2016 based on Worldview**

Categories	2015 (Spot)		2016 Worldview-2	
	ha	%	ha	%
Closed Forest	55654.65	32.74	81795.86	48.12
Open Forest	64271.65	37.81	52309.50	30.77
<b>Total Forest Cover</b>	<b>119926.3</b>	<b>70.55</b>	<b>134105.36</b>	<b>78.89</b>
other wooded land	44452.96	26.15	31612.87	18.60
Water	285.55	0.17	2.54	0.00
cultivated land	876.61	0.52	2593.04	1.53
others	513.37	0.30	1490.81	0.88
Plantation	3944.21	2.32	194.38	0.11
Total	169999	100	169999.00	100

**Table 7: Land use and Land cover of TNR and its surroundings in 2015 based on Landsat 8**

No	Land use and Land cover categories	TNR Area		10 km Outside of TNR		Surrounding TNRP		all area	
		ha	%	ha	%	ha	%	ha	%
1	Closed Forest	96661.46	56.86	1118.12	0.72	26558.96	15.53	124338.54	25.06
2	Open Forest	33827.82	19.90	30741.44	19.81	40174.59	23.49	104743.86	21.11
3	Water body	413.04	0.24	1118.12	0.72	26558.96	15.53	28090.12	5.66
4	Agriculture Land	618.79	0.36	4531.11	2.92	16992.61	9.93	22142.52	4.46
5	Mangrove Forest	0.00	0.00	0.00	0.00	8599.17	5.03	8599.17	1.73
6	Grass Land	4286.67	2.52	11423.46	7.36	16170.47	9.45	31880.60	6.42
7	Dry Grass	0.00	0.00	2691.15	1.73	367.47	0.21	3058.62	0.62
8	Sand	41.82	0.02	138.36	0.09	1188.00	0.69	1368.18	0.28
9	Young Rubber	70.99	0.04	7848.26	5.06	4134.29	2.42	12053.53	2.43
10	Bamboo	9438.83	5.55	6716.67	4.33	5684.28	3.32	21839.78	4.40
11	Scrub Land	24117.37	14.19	60136.69	38.75	33125.42	19.37	117379.48	23.65
12	Perennial crops, home garden, horticulture	2.18	0.00	2417.21	1.56	858.98	0.50	3278.36	0.66
13	Others	433.46	0.25	921.58	0.59	1401.27	0.82	2756.31	0.56
14	Oil Palm	0.00	0.00	1493.59	0.96	707.22	0.41	2200.81	0.44
15	Shifting cultivation	37.42	0.04	1364.34	0.88	504.52	0.29	1906.28	0.38
16	Old Rubber	49.14	0.03	3692.69	2.38	5316.12	3.11	9057.95	1.83
		169999.00	100.00	155196.03	100.00	171047.45	100	496242.48	100

Notes: All area: All assessed areas



### 5.3. Brief description on land use and land cover changes of TNR and its surroundings

Assessment by Landsat satellite covered an area of 49,6242 ha in total. We divided the assessed areas into three areas, i.e. TNR core, 10 kilometer outside of TNR core and surrounding of TNR (outside of 10 kilometer of TNR and the area covers all land area until to costal line) regarding to understand how land use and land cover of inside of TNR and its surrounding areas. Table 7 represents the land use and land covert status by three assessed areas of TNR and its neighboring in 1990, 2006 and 2015. As mention before, among 16 categories, forest area of TNR covered around 76% of the total area of TNR. In addition, if we considered the all vegetation cover, i.e. consisting of the other wooded land, almost all TNR area was covered by trees and other vegetation; 99.02% (168332.15ha) by Landsat 8. Other land use and land cover areas were quite low inside TNR.

However, there was about 60136.69 ha of scrub land (38.75%), it was the largest dominant land cover within the 10km outside area of TNR followed by open forest area. Forest covered around 20 % of the respective area, i.e. closed forest 0.72 % (1118.12 ha) and open forest 19.81% (30741.44 ha). Open forest area was the largest dominant land cover in surrounding TNR (23.49% - 40174.59 ha).

Although there were sixteen categories in current land use and land cover assessment, we compared the changes by means of twelve categories due to data sources of 1990 and 2006. Table 8, Table 9, Table 10 and Table 11 represent the areas of land use and land cover and their percentage in 1990, 2006 and 2015 of TNR, 10km outside, surrounding TNR and all assessment areas respectively.

Table 8: Land use and Land cover of TNR area in 1990, 2006 and 2015

No	Categories	1990		2006		2015	
		ha	%	ha	%	ha	%
1	Closed Forest	132822.1	78.13	105471	62.04	96661.46	56.86
2	Open Forest	18578.46	10.93	24948.81	14.68	33827.82	19.90
3	Water	336.46	0.20	1201.33	0.71	413.04	0.24
4	Agriculture	788.92	0.46	1218.02	0.72	618.79326	0.36
5	Grass Land	227.5	0.13	2499.14	1.47	4286.6682	2.52
6	Sand	-	0.00	123.04	0.07	41.8208	0.02
7	Rubber	162.25	0.10	186.62	0.11	120.13	0.07
8	Bamboo	5120.1	3.01	14144.64	8.32	9438.8304	5.55
9	Scurb land	11915.61	7.01	19976.2	11.75	24117.374	14.19
10	Horticulture	47.6	0.03	87.17	0.05	39.602769	0.02
11	Others	-	-	141.6	0.08	433.46451	0.25
12	Oil Palm	-	-	1.43	0.00	-	-
		169999.00	100	169999.00	100	169999.00	100.00

Table 9: Land use and Land cover of TNR 10km surrounding area in 1990, 2006 and 2015

No	Categories	1990		2006		2015	
		ha	%	ha	%	ha	%
1	Closed Forest	58245.19	37.53	43992.78	28.35	1118.12	0.72
2	Open Forest	9586.38	6.18	4728.96	3.05	30741.44	19.81
3	Water	1229.93	0.79	1665.52	1.07	1118.12	0.72
4	Agriculture	11093.37	7.15	14931.62	9.62	4531.11	2.92
5	Grass Land	2187.16	1.41	7688.91	4.95	0.00	0.00
6	Sand	1.96	0.00	356.06	0.23	11423.46	7.36
7	Rubber	1012.10	0.65	1537.43	0.99	2691.15	1.73
8	Bamboo	4615.93	2.97	15443.80	9.95	138.36	0.09
9	Scurb land	63739.26	41.07	53162.30	34.25	7848.26	5.06
10	Horticulture	3482.04	2.24	11227.54	7.23	6716.67	4.33
11	Others	0.00	0.00	226.49	0.15	60136.69	38.75
12	Oil Palm	2.73	0.00	234.61	0.15	2417.21	1.56
		155196.03	100.00	155196.03	100.00	155196.03	100.00

Table 10: Land use and Land cover of surrounding TNR area in 1990, 2006 and 2015

No	Categories	1990		2006		2015	
		ha	%	ha	%	ha	%
1	Closed Forest	53598.69	31.34	62357.28	36.46	26558.96	15.53
2	Open Forest	17202.61	10.06	235.75	0.14	40174.59	23.49
3	Water	25287.12	14.78	27408.12	16.02	26558.96	15.53
4	Agriculture	22335.02	13.06	19415.20	11.35	16992.61	9.93
5	Grass Land	1513.72	0.88	1712.29	1.00	8599.17	5.03
6	Sand	684.32	0.40	1270.23	0.74	16170.47	9.45
7	Rubber	274.81	0.16	657.64	0.38	367.47	0.21
8	Bamboo	1200.79	0.70	8463.16	4.95	1188.00	0.69
9	Scurb land	45708.83	26.72	40943.85	23.94	4134.29	2.42
10	Horticulture	3241.35	1.90	8436.22	4.93	5684.28	3.32
11	Others	-	-	133.63	0.08	33125.42	19.37
12	Oil Palm	0.18	0.00	14.07	0.01	858.98	0.50
		171047.44	100	171047.44	100	171047.44	100

Table 11: Land use and Land cover of TNR and its surroundings (all assessed area) in 1990, 2006 and 2015

No	Categories	1990		2006		2015	
		ha	%	ha	%	ha	%
1	Closed Forest	244666.00	49.30	211821.00	42.68	124338.54	25.06
2	Open Forest	45367.45	9.14	29913.52	6.03	104743.86	21.11
3	Water	26853.52	5.41	30274.97	6.10	28090.12	5.66
4	Agriculture	34217.31	6.90	35564.85	7.17	22142.52	4.46
5	Grass Land	3928.38	0.79	11900.34	2.40	8599.17	1.73
6	Sand	686.28	0.14	1749.33	0.35	31880.60	6.42
7	Rubber	1449.16	0.29	2381.76	0.48	3058.62	0.62
8	Bamboo	10936.78	2.20	38051.60	7.67	1368.18	0.28
9	Scurb land	121363.70	24.46	114082.32	22.99	12053.53	2.43
10	Horticulture	6770.99	1.36	19750.93	3.98	21839.78	4.40
11	Others	0.00	0.00	501.75	0.10	117379.48	23.65
12	Oil Palm	2.90	0.00	250.11	0.05	3278.36	0.66
		496242.45	100.00	496242.45	100.00	496242.45	100.00

#### 5.4. Forest cover changes of TNR and its surroundings

As deforestation and forest degradation are leading to major threats to the flora and fauna living therein (Zhao et al., 2006), comparison of forest cover was also conducted in this study. TNR project was started in 2005 and therefore, forest cover areas were compared for the period 1990, 2006 and 2015 in order to understand how land use and land cover before and after establishing TNR. Figure 1 shows the comparison of forest areas of TNR and its surroundings. Although forest cover was decreased during 1990 and 2006, almost same forest cover was assessed between 2006 and 2016 when forest cover is still decreasing within the 10km outside area of TNR. But decreased of forest cover was found 10 km outside of TNR and its surrounding.

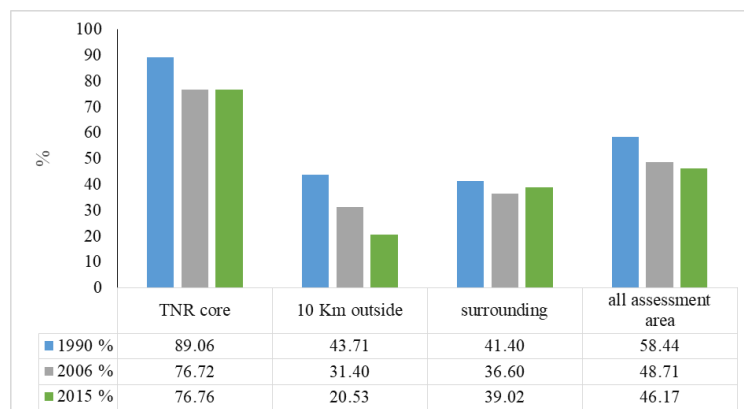


Figure 1: Comparison on Forest Cover (Closed and Open Forest) in 1990, 2006 and 2015

## 5.5. Deforestation analysis

### 5.5.1. Deforestation analysis by landsat

As deforestation is leading to major threats to the flora and fauna living therein (Zhao et al., 2006), deforestation analysis was also conducted in this report. TNR project was started in 2005 and therefore, deforestation analysis was conducted for the period 1990-2006 and 2006-2010 in order to compare how land use and land cover before and after establishing TNR. Table 12 and Figure 1 shows the comparison of deforestation rates of TNR and its surroundings.

Table 12: Deforestation rates of TNR and its surroundings

deforestation rate (%)	Surrounding		TNR area
	TNR	10 km outside of TNR	
1990-2006	-0.72	-1.76	-0.87
2006-2015	0.73	-3.85	0.01

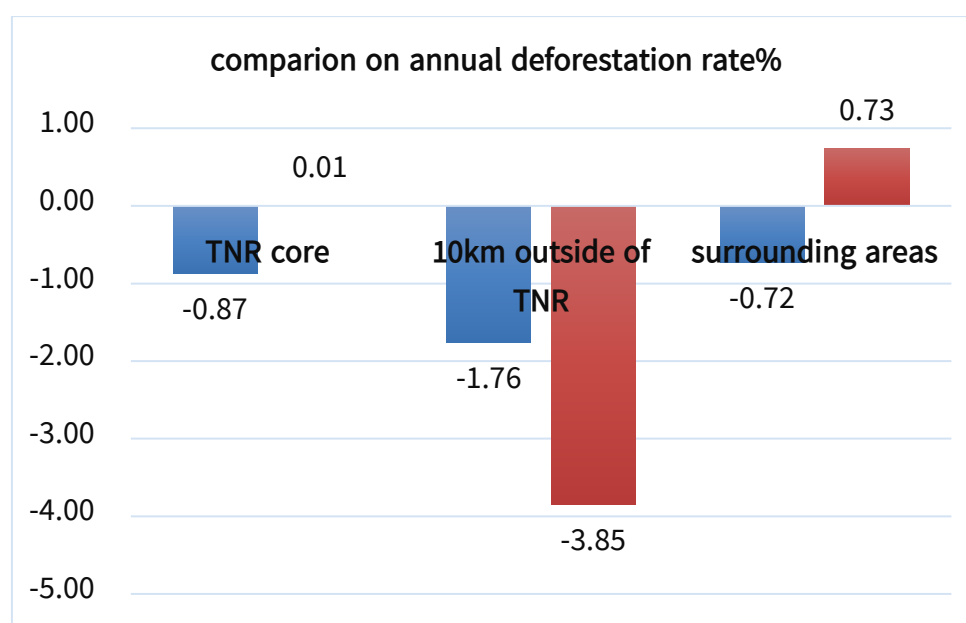


Figure 1: Deforestation rates of TNR and its surroundings

Results on deforestation analysis show that rates of net deforestation in TNR area was -0.87% whereas there was no deforestation with the rate of 0.01%. Within the 10km outside areas of TNR, rates of net deforestation during the period from 2006-2015 were higher than that of 1990-2006 periods; i.e. -1.76% and -3.85% respectively. According to the assessment, we found that mangrove forest areas are increasing and thus why rates of net deforestation in surrounding area was -0.72% whereas there was no deforestation with the rate of 0.73%.

Deforestation analysis indicated that effectiveness of TNR project initiated when there was high deforestation rate nearby areas.

### 5.5.2. Deforestation analysis by Spot 2015 and Worldview 2016

As we mention before, although there is different in spatial resolution of source data sets, we did change matrix as follows in order to understand the effects of these differences;

Table 13: Change Matrix of land use and land cover by Spot 2015 and Worldview 2016

Land use and land cover		2016							Grand Total 2015
		1	2	3	4	5	6	7	
2015	1	35717.74	12438.26	2752.48	0.04	62.97	176.82	12.39	51160.69
	2	28068.31	22857.04	8027.65	0.23	145.87	444.03	24.81	59567.93
	3	10824.02	12114.18	15545.03	0.60	1768.81	561.03	52.74	40866.40
	4	20.29	34.27	174.61	1.47	60.51	9.83	1.17	302.15
	5	379.04	543.66	2300.09	0.00	332.80	37.21	5.75	3598.54
	6	75.91	50.58	177.74	0.00	6.51	107.61	25.88	444.22
	7	71.15	25.52	69.25	0.00	5.10	33.28	55.86	260.17
	Grand Total 2016	75156.45	48063.51	29046.84	2.33	2382.56	1369.80	178.60	156200.09

Notes: 1-Closed Forest, 2-Open Forest, 3-Other wooded land, 4-Cultivated Land, 5-plantation, 6-others, 7-water

Change matrix only covered the areas of 156200 ha and the above table also shows that the total areas of forest areas increased from 110728.62 ha to 123219.96 ha during the period of 2015 and 2016. In practical, this might not be such kind of quick change. We assumed that thresholds of closed, open and otherwooded land is not quite clear in image classification. More high resolution images provided more fine data and information of land use and land cover.

## 6. Discussions

Sustainability of TNR is necessary and deforestation and forest degradation can be prevented through the application of effective management. With this respect, monitoring and assessment on land use and land cover change was conducted to provide spatial information for effective remedial measures. During the assessment periods; 1990 to 2006 and 2006 to 2016, closed forest areas of TNR were gradually lost but this might be due to the effect of image classification and this is one of the limitation of remote sensing. Although we defined the forest cover very specifically by canopy density %, it was very difficult in image classification by maximum likelihood classification.

In image classification, more heterogeneous land use and land cover categories; such as mixed with open forest and other wooded land, bamboo dominant forests, horticulture lands, etc..., generated more complex patterns of spectral reflectance, and thus the results were leading to lower accuracies. We combined the land categories into seven major land use and land cover categories due to insufficient representative of field data. Shifting cultivation, scrub and grass land also have complex reflectance patterns, which may be similar to the reflectance patterns between themselves. Similarly, we classified young and old rubber plantation, oil palm plantation separately, but we finally combined them as one category; plantation for accuracy check. Although the interpreters have the knowledge related with spectral characteristics of satellite images, land use and land cover pattern, it is still needed many field information or ground information. In order to improve monitoring and assessment results, we should consider the following factors;

- Sufficient field data or ground references should be collected to represent every land cover categories of the study area
- Field data collection time should be same with satellite image acquisition date to avoid the different characteristics of land use and land cover in the field and image visualization. It should be planned and adjusted between the possible time to do field survey (ground data collection) and images acquisition date.
- Same spatial resolution of remote sensing data/satellite imageries should be used to exclude the errors in conducting change detection between the land use and land cover categories of different periods.
- Same image classification techniques and procedures should be applied for continuous assessment and if possible same interpreters should be assigned to avoid the different ideas on training data selection in image classification.
- And the interpreters should conduct field survey by himself or herself in order to get knowledge of land use and land cover of the study area and improve classification accuracy.

## **7. Conclusion**

In Myanmar, TNRP is also an important one due to its unique biodiversity among the being established and proposed PASs. It is necessary to practice biodiversity conservation in this region and to implement remedial measures for sustainable development. Assessment of the forest extents and conditions is also essential for the sustainable development of TNR. Land use and Land cover change has been attributed by various reasons and those reasons are site

specific. Land cover conversion pattern varies from place to place (Giri et al., 2003). With this regards, assessment on land use and land cover changes was conducted not only for TNR but also for outside areas to provide information for effective management. Land use and land cover of TNR should be continuously monitored to provide updated information. This study used integrated application of RS and GIS for land use and land cover changes. This study was focused for the image classification of TNR area and it is also need to assess in details for its surrounding. It is still needed to study deeply on deforestation and forest degradation and why happen in surrounding of TNR together with socio-economic and their related factors using RS and GIS. However, we would like to conclude that TNR area has still very good forest cover; i.e. over 70% of closed and open forest and around 95% of total land areas was covered by tree vegetation if we considered other wooded land as vegetation cover/tree cover. Finally, the team recommended to use both high and medium resolution satellite images for next assessment regarding to continue consistent data sources.

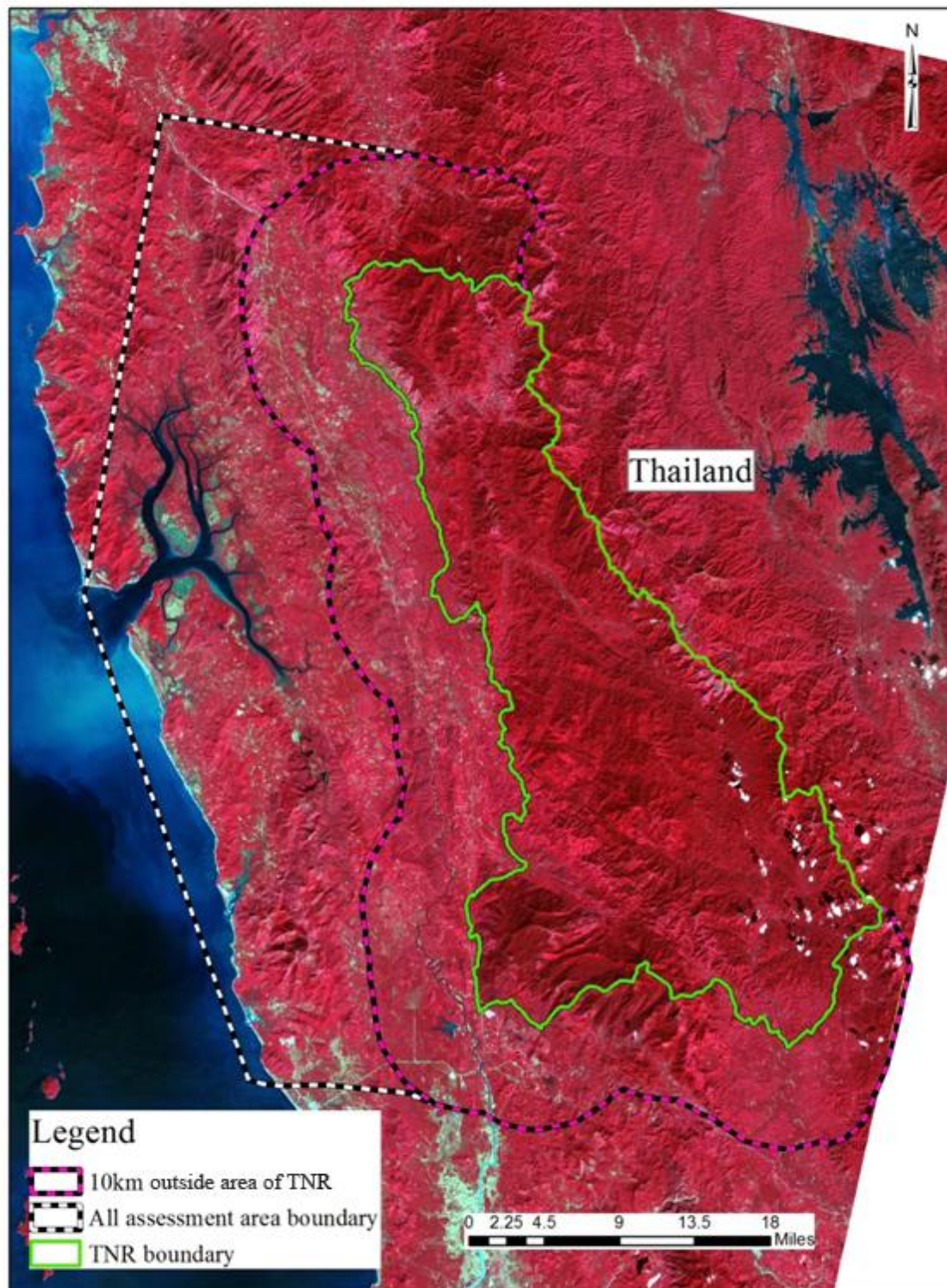
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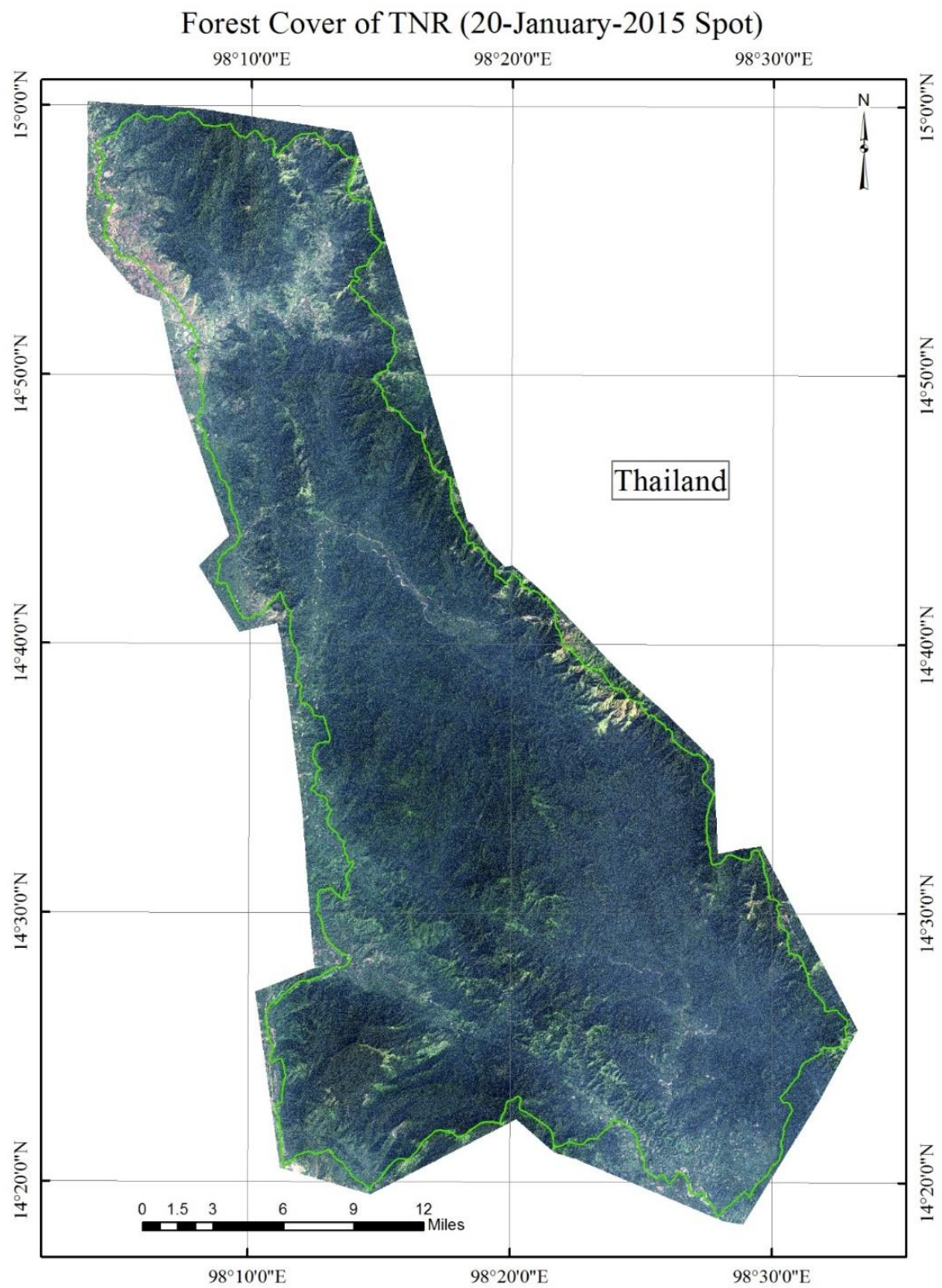
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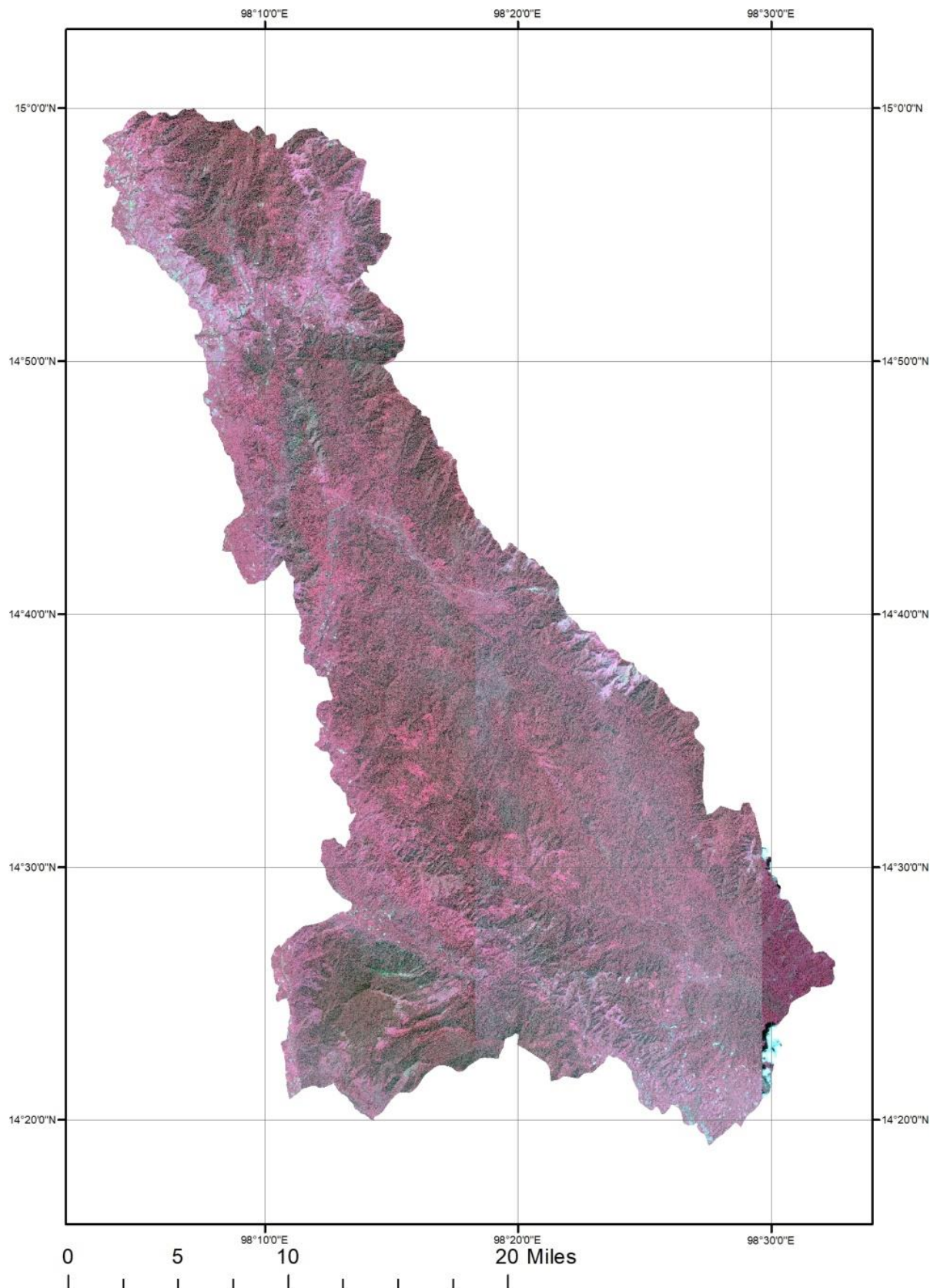
# TNR Area and its surroundings (5-February-2015 Landsat 8)



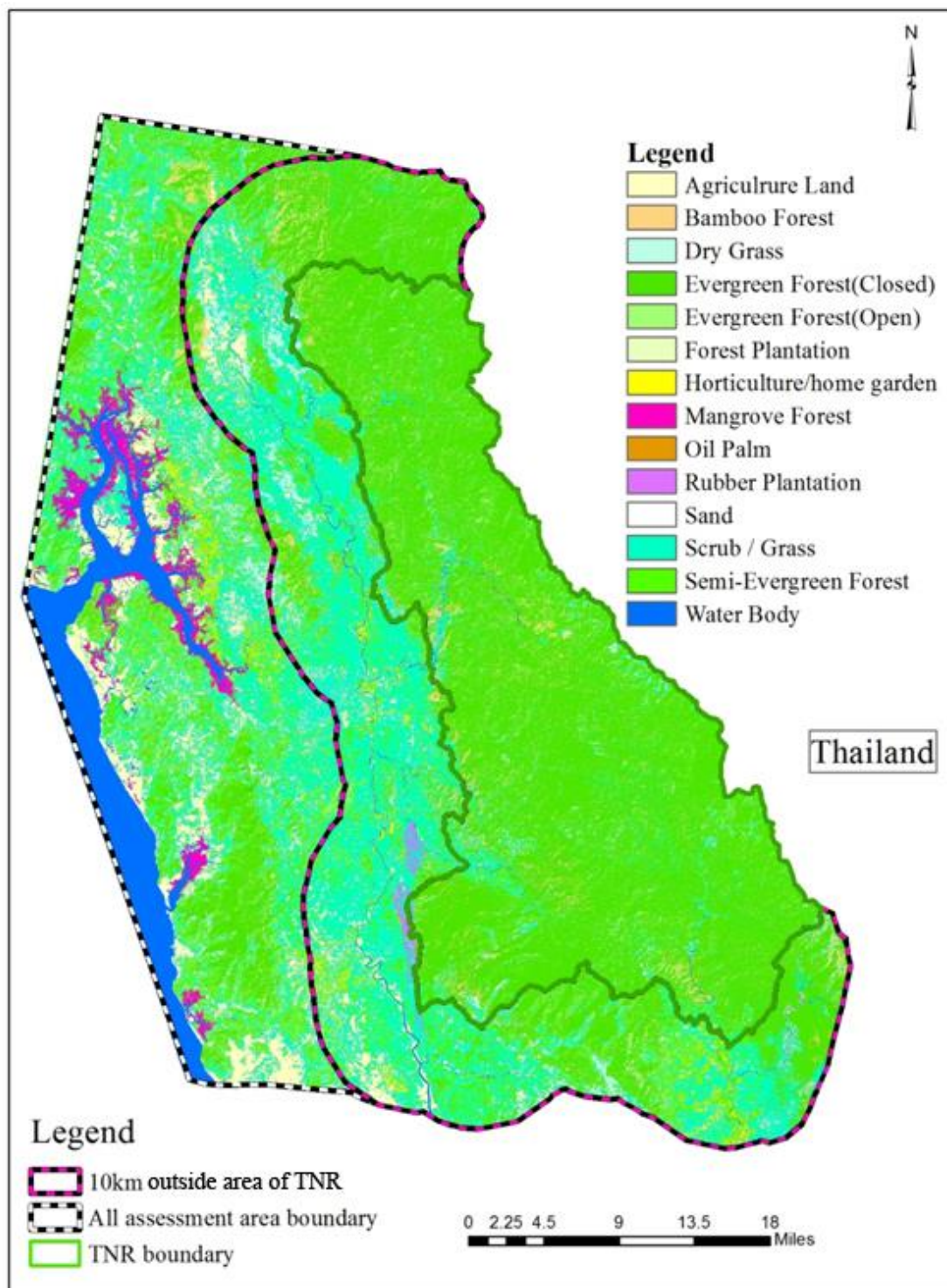




TNRP area (Worldview image, 2016-November)

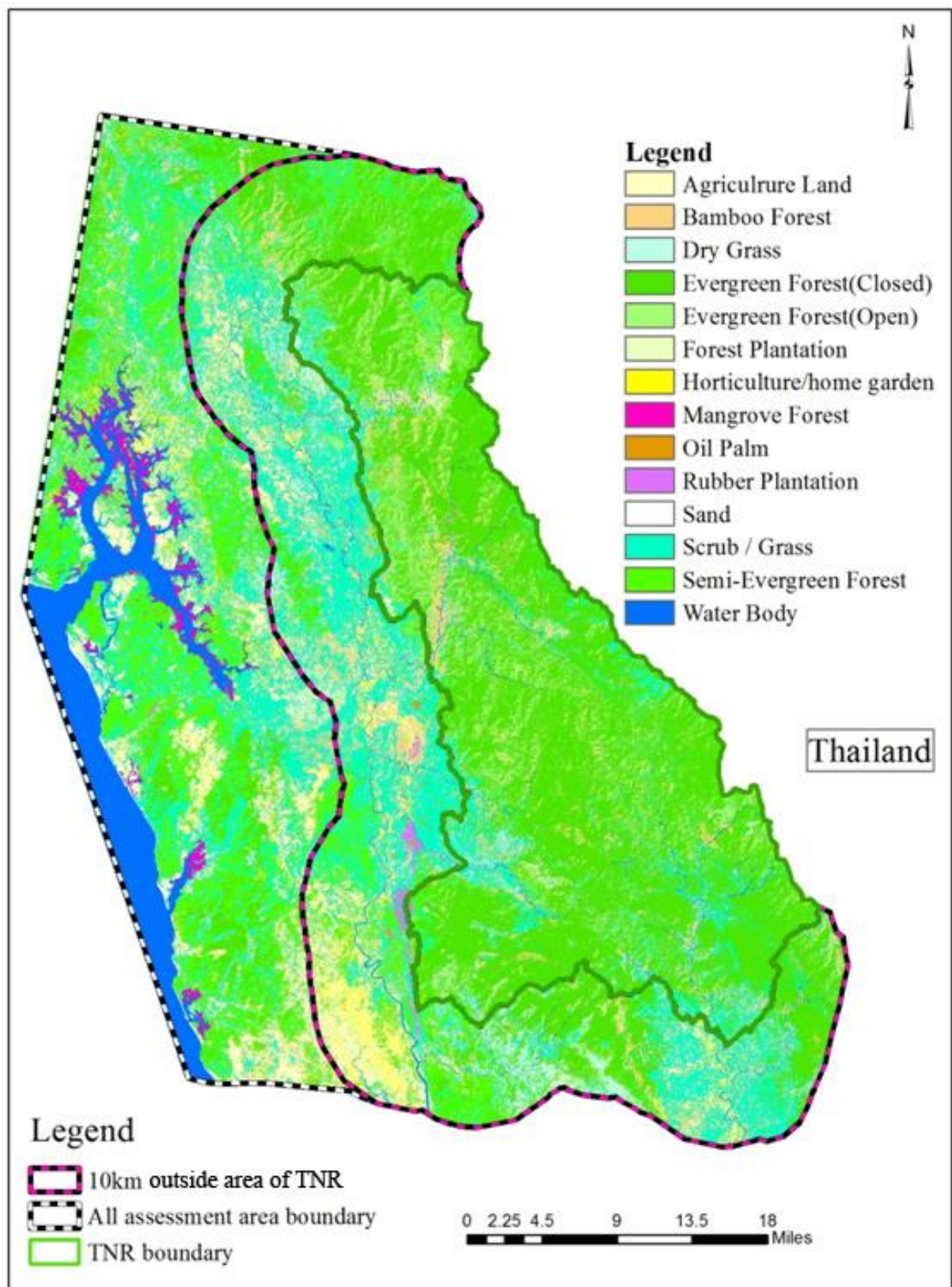


## TNR Area and its surroundings (1990)

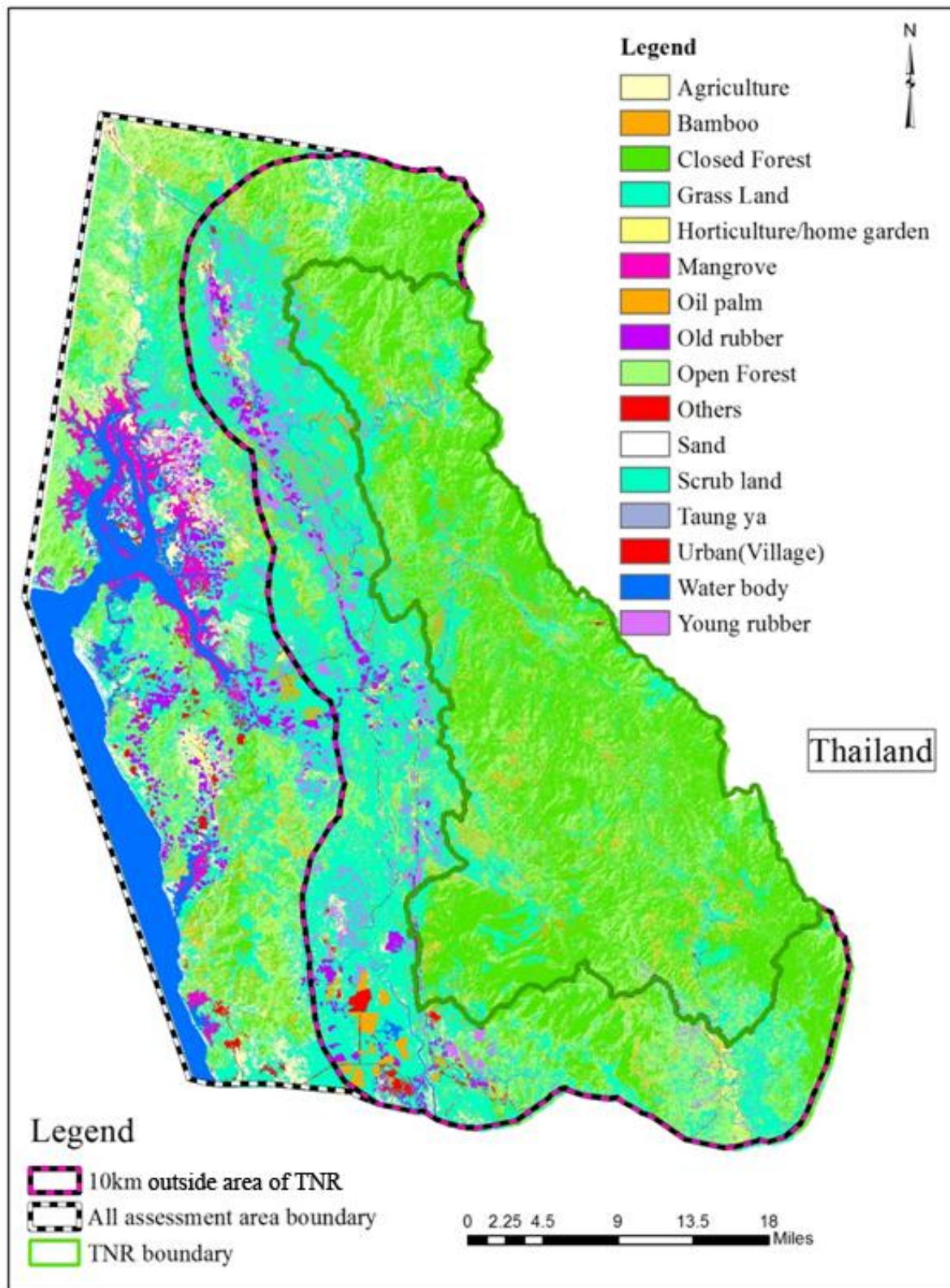




## TNR Area and its surroundings (2006)

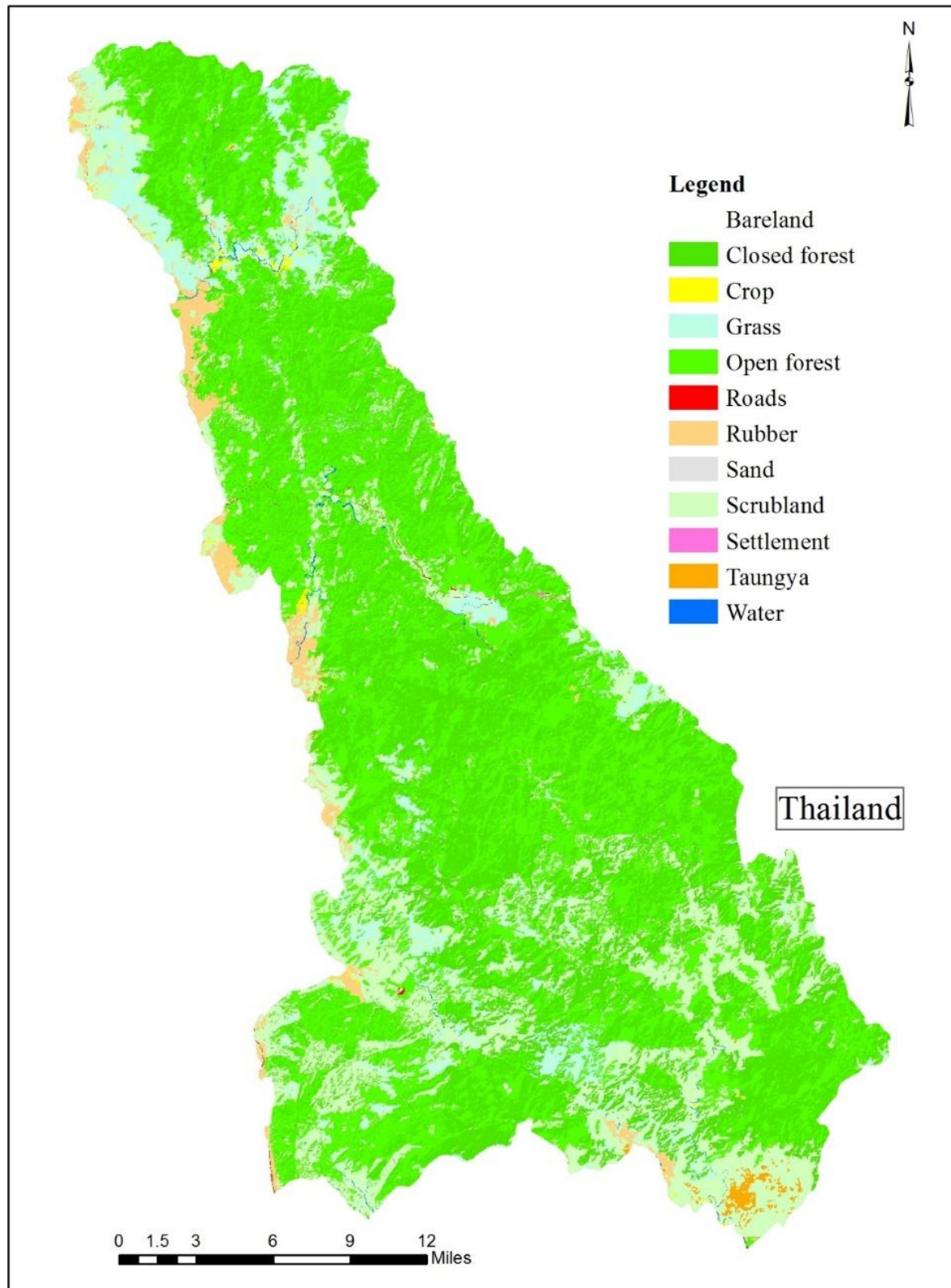


## TNR Area and its surroundings (2015)





# Land Use and Land Cover of TNR area by 2015 Spot 7



Land Use and Land Cover by Worldview image(2016)

