Ministry of Environmental Conservation and Forestry

Forest Department

Planning and Statistics Division

RS and GIS Section

Assessment on Land Use and Land Cover ofTanintharyi Nature Reserve and its Surroundings using RS and GIS

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Executive Summary

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, socioeconomic, and policy studies to support effective management mechanisms. Realizing the need to provide information on the present status of major land cover types of the region, Remote Sensing and GIS section of Forest Department conducted monitoring on land use and land cover of in and around TNR areas periodically using various satellite images. By comparing major land use and cover of TNR between 2006 and 2015separately in three areas; TNR area, 10 km buffer area of TNR and outside of TNR area, the results revealed that although forest cover was quite stable within TNR area, decreasing of forest cover areas was resulted within 10 km buffer area of TNR and its outside 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 forestsis 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^2at 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 2010and 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. 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 2015were applied regarding to provide updatedmore and more information for management mechanisms.

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 30th 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 and 2006 were used to understand the trend of land use and land cover changes not only for TNR area but also within 10 km buffer of TNR boundary (TNR buffer) and outside of these areas (outside 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 2006 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 activities 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 current land use/land cover map 2015 of the study area

(2) Comparison on land use/land cover in different periods; i.e. 1990, 2006, and 2015 based on Landsat image classification

Table 1: Land use and Land cover status of TNR and its surrounding in 1990 and 2006

Area (ha)

No.	Lu/Lc categories	TNR Area		10 km Buffer Area		Outside TNR	
		1990	2006	1990	2006	1990	2006
1	Closed Forest	132,822.12	105,470.94	58,245.19	43,992.78	53,598.69	62,357.28
2	Open Forest	18,578.47	24,948.82	9,586.38	4,728.96	17,202.61	235.75
3	Water	336.47	1,201.33	1,229.93	1,665.52	25,287.12	27,408.12
4	Agriculture	788.92	1,218.02	11,093.37	14,931.62	22,335.02	19,415.20
5	Grass Land	227.51	2,499.13	2,187.16	7,688.91	1,513.72	1,712.29
6	Sand	0	123.04	1.96	356.06	684.32	1,270.23
7	Rubber	162.25	186.69	1,012.10	1,537.43	274.81	657.64
8	Bamboo	5,120.06	14,144.64	4,615.93	15,443.80	1,200.79	8,463.16
9	Scurb/grass	11,915.62	19,976.17	63,739.26	53,162.30	45,708.83	40,943.85
10	Horticulture	47.59	87.18	3,482.04	11,227.54	3,241.35	8,436.22
11	Others	0	141.63	0	226.49	0	133.63
12	Oil Palm	0	1.42	2.73	234.61	0.18	14.07
	Total	169,999.00	169,999.00	155,196.03	155,196.03	171,047.45	171,047.45

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, TaninthayiRegion, 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^2 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 roundabout 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 to18°C around January (Dawei District Forest Management Plan).

4.2. Data Sources

Landsat TM images with 30 m spatial resolution were used in previous 1990 and 2006 assessment. Due to the quality of Landsat satellite scenes around 2010, four ALOS (AVNIR-2) satellite image data sets with 10 m spatial resolution acquired on 5-December-2009 and 26-February-2010 were used for2010 land use/land cover assessment.

High resolution Spot 7 satellite images with 6 m spatial resolution of Multispectral bands: Blue, Green, Red, Near Infrared and 1.6 m spatial resolution of Panchromatic were applied after Pan-sharping process. Spot images were acquired on 20-January-2015. This was the first time in using of very high satellite images for land use and land cover assessment of the whole TNR area.

In addition, we used Landsat 8 satellite images (spatial resolution of 30 m) acquired on5-February-2015in order to avoid the inconsistency; i.e. different resolution satellite images and different methods were not recommended for comparison. The following table shows the summary of data sources used for land use and land cover assessment.

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

Satellite	Year	Acquisition Dates	Spatial Resolution (pixel size)
Landsat TM	1990		30m x 30m
Landsat TM	2006		30m x 30m
ALOS	2010	5-12-2009 and 26-2-2010	10m x 10m
Landsat 8	2015	5-2-2015	30m x 30m
Spot 7	2015	20-1-2015	6 m x 6 m (Multispectral) 1.6 m x 1.6 m (Panchromatic)

4.3. Satellite Image Classification

Although a supervised image classification was used in assessment of land use/land cover of TNR in 2006, 2010 ALOS and 2015 Landsat images, object-based image classification was applied for 2015 Spot image classification because most studied suggested to use this method for high resolution images.

Object-based image classification was conducted by using ENVI 5.2 based on information from a set of similar pixels and a measure of spectral properties of the pixels.

After getting the segmentation results, the polygons were manually assigned into respective land cover categories using ArcGIS 10.2.2.

For supervised image classification, the basic steps, such as training stage, feature selection, selection of appropriate classification algorithm, post classification smoothening and accuracy assessment were involved in the classification procedure.In training area selection, images 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.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.

Ground verification records and previous digital land use/land cover maps were also used during the selection of training areas and also in assigning land cover categories 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., 16 of land cover categories related to TNRP area were selected to perform supervised classification. Classified land cover classes were combined into twelve land cover classes in order to compare with compare with previous assessment results. These were finally combined into seven categories for accuracy assessment and change detection between 2010 and 2015(Table 3).

Table 3:Re-categorized land use and land cover classes in 2010 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/ Horticulture/home garden	
7	dry grass	Other wooded land
8	Grass land	
9	scrub land	
10	shifting cultivation (practiced many years ago)	
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 then 10 percent 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 undergrowth 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 10percent.

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 **v**egetation 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 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) to120inches, 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* (*Oxytenantheranigrociliata*). These forests provide anumber of species of commercial importance amongst which are *Kanyin-byu*and Kanyin-ni(*Dipterocarpusalatus*and *turbinatus*), *thingan*(*Hopeaodorata*), *Kaunghmuorthingadu*(*Parashoreastellata*), *kamaung*or *pyinma*(*Lagerstroemia speciosa*), *thitka*(*Pentaceburmanica*), *shitle*or *taungthayet*(*Swintonia floribunda*) and *baing*(*Tetramelesnudiflora*).

Evergreen Forest (Open): Same as above mentioned type except that the forests included considerable open-space.

Semi Evergreen Forest: It is intermediate between TropicalEvergreen and the Moist Deciduous Forests. Evergreen and deciduous dominants occur usuallymixed fairly intimately though local patches of almost pure dominants may occur. The lower storeyis mainly evergreen and bamboos are usually present. The common species are Pyinkado(*Xyliadolabriformis*) and Kanyin(*D. turbinatus*). Other species are Myaukchaw(*Homaliumtomentosum*),Yemane(*Gmelinaarborea*),

Gyo(*Scheicheratrijuga*), *Lagerstroemia* species and Bambwe(*Careyaarborea*). Kyathaung(*Bambusapolymopha*) is the most common bamboo. Waphyu

(*Dendrocalamusmembraceus*) and Tin(*Cephalostachyunpergracile*) are frequently foundtogether.

Bamboodominant 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.

Grass Land: Grass Lands are mostly consequent of repeated shifting cultivation or forest cuttings. These lands are mostly affected by repeated forest fire and some are rocky mountains with shallow and poor soil effect.

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.

Perennial Crops, Home garden, 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.

Rubber Plantation: Most of these are government owned plantations. It can be found along the road side.

Oil palm: These can be found on the way from Kaleinaung village to Yephyu town.

Agriculture Land: This is normal agriculture land with annually cultivation consisting of dry land agriculture, irrigated areas, agriculture crops and nearly harvest crops.

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.

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 102 references were used for accuracy assessment. Land use and land cover of TNR was finally categorized into seven major classes including, forest (closed), forest and bamboo dominant areas (open), agriculture lands (cultivated lands, home garden and Horticulture), waterbody, other wooded land (scrub land, grass land), others (buildup areas, sand etc.) and plantation (rubber and oil palm).

Classification accuracy of land use and land cover thematic maps with seven major classes was checked using GPS and Google Earth references.

4.6. Limitation of the Assessment

Although we classified high resolution images for 2015, it was impossible to compare with previous 2010 and 2006 land use and land cover assessment. On the other hands, actual change can be obtained by a direct comparison between classification results of one date with the other date. Unfortunately, classification methodology was quite differ from the previous assessment and change detection could not be conducted due to data limitation.

5. Results

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

5.1.1. Accuracy assessment of Spot 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., 81 of 102 observations were correctly classified with an overall accuracy of 79.41 % and a kappa coefficient of 0.745. 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 open forest, cultivated landand plantation categories, i.e. user's accuracy of 75.00%, 66.67%and 50% respectivelywhen producer's accuracies were 52.94%, 100% and 80% respectively (Table 4).

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

	Classified								User's accuracy
references		1	2	3	4	5	6	7	Total	
	1	20	5	0	0	0	0	0	25	80.00
	2	1	9	0	0	1	1	0	12	75.00
	3	0	0	10	0	0	0	0	10	100.00
	4	0	0	0	4	2	0	0	6	66.67
	5	0	2	1	0	25	3	0	31	80.65
	6	0	0	0	0	0	9	1	10	90.00
	7	0	1	0	0	3	0	4	8	50.00

Total	21	17	11	4	31	13	5	102
Producer's accuracy	95.24	52.94	90.91	100	80.65	69.23	80.00	
Overall accuracy= 79.41%								
Kappa Statistics= 0.745								

Notes:1-forest (closed), 2-forest (open), 3-waterbody, 4- cultivated lands (agriculture lands and Horticulture), 5-other wooded land (scrub land, grass land), 6-others (buildup areas, sand etc) and 7-plantation (rubber and oil palm).

5.1.2. Accuracy assessment of Landsat Classification

The error matrix of reference and classified land use and land cover categories shows the accuracy classification, i.e., 75 of 102 observations were correctly classified with an overall accuracy of 73.53%and a kappa coefficient of 0.672. Table 5presents accuracy information of land use and land cover categories by procedure's and user's accuracies. Both user's and producer's accuracies were high in all land use land cover categories except in open forests, i.e. user's accuracy of 75.00% and producer's accuracy of 42.86% (Table 5).

Table 5: Error Matrix of reference and classified land use and land cover categories

	Classified								User's accuracy
references		1	2	3	4	5	6	7	Total	
	1	15	6	0	2	2	0	0	25	60.00
	2	0	9	0	0	3	0	0	12	75.00
	3	0	0	10	0	0	0	0	10	100.00
	4	0	0	0	6	0	0	0	6	100.00
	5	1	5	0	0	25	0	0	31	80.65
	6	0	0	0	0	4	6	0	10	60.00
	7	0	1	0	0	2	1	4	8	50.00
Total		16	21	10	8	36	7	4	102	
Producer's accuracy		93.75	42.86	100.00	75.00	69.44	85.71	100		
Overall accuracy= 73.53%										
Kappa Statistics= 0.672										

Notes:1-forest (closed), 2-forest (open), 3-waterbody, 4-cultivated lands (agriculture lands and Horticulture), 5-other wooded land (scrub land, grass land), 6-others (buildup areas, sand etc) and 7-plantation (rubber and oil palm).

5.2. Land use and Land cover of TNR area

Table 6 represents the land use and land covert status of three assessed areas of TNR area in 2010 and 2015. 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 70% of the total area of TNR in 2015, i.e. closed forest 32.74% (55654.65ha) and open forest 37.81% (64271.65ha) based on Spot image and closed forest 56.86% (96661.46ha) and open forest 19.90% (33827.82ha) based on Landsat 8. Second larger cover was other wooded land, i.e. 26.15% of TNR (44452.96ha) by Spot and 22.26% of TNR (37842.87ha) by Landsat 8 respectively.

Table 6: Land use and Land cover of TNR in 2010 based on ALOS images and 2015 based on Spot and Landsat images

Categories	2010 (ALOS)		2015 (Landsat)		2015 (Spot)	
	ha	%	ha	%	ha	%
Closed Forest	99705.04	58.65	96661.46	56.86	55654.65	32.74
Open Forest	35503.41	20.88	33827.82	19.90	64271.65	37.81
Total Forest Cover	**135208.50**	**79.53**	**130489.28**	**76.76**	**119926.3**	**70.55**
other wooded land	33011.71	19.42	37842.87	22.26	44452.96	26.15
Water	724.59	0.43	413.04	0.24	285.55	0.17
cultivated land	628.58	0.37	658.40	0.39	876.61	0.52
others	266.81	0.16	475.29	0.28	513.37	0.30
Plantation	158.86	0.09	120.13	0.07	3944.21	2.32
Total	169999	100	169999	100	169999	100

Assessment by Landsat 8covered an area ofaround490,000 ha. We divided the assessed areas into three areas, i.e. TNR core, 10 kilometer buffer of TNR core and outside of TNR (outside of 10 kilometer buffer of TNR and the area covers all land area until to costal line) regarding to understand the current land use and land cover of TNR and its surrounding areas. Table 7 represents the land use and land covert status of three assessed areas of TNR and its neighboring in 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; i.e. 96.69% (164379.30 ha) by Spot and 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 10 km buffer 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 outside TNR (23.49% - 40174.59 ha).

Table 7: Land use and Land cover of TNR and its surroundingsin 2015 based on Landsat 8

No	Land use and Land cover categories	TNR Area		10 km Buffer of TNR		Outside 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	Horticulture Land	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	Taungya	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

4.1. Brief description on land use and land cover changes in and around TNR by Landsat 8 classification

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, 10 km buffer, outside 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 10 km buffer 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 outside TNR area in 1990, 2006 and 2015

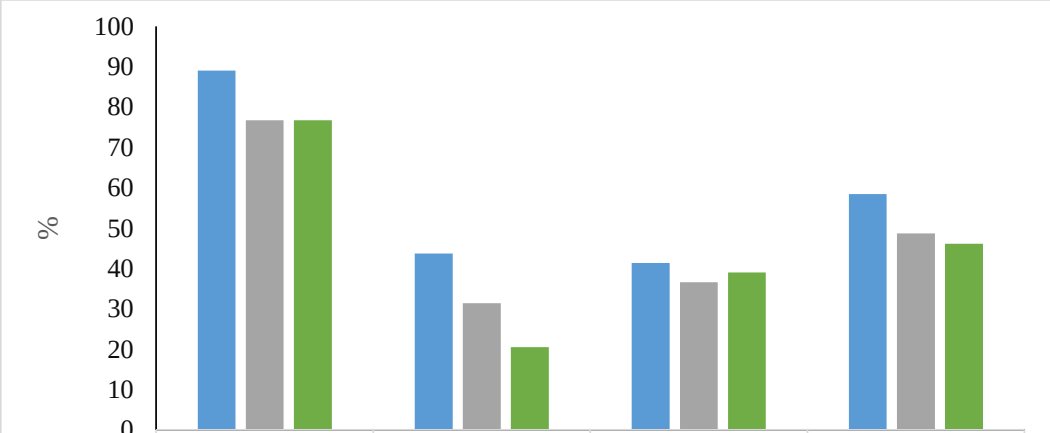
No	Categories	1990		2006		2015	
		ha	%	ha	%	ha	%
1	Closed Forest	53598.69	31.34	62357.28	36.46	26558.96	15.53
2	Open Forest	17202.61	10.06	235.75	0.14	40174.59	23.49
3	Water	25287.12	14.78	27408.12	16.02	26558.96	15.53
4	Agriculture	22335.02	13.06	19415.20	11.35	16992.61	9.93
5	Grass Land	1513.72	0.88	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

4.2. 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 10 km buffer area of TNR. But decreased of forest cover was found outside of TNR and its buffer.



	only TNR	10 Km buffer	outside TNR	all assessed area
1990 %	89.06	43.71	41.40	58.44
2006 %	76.72	31.40	36.60	48.71
2015 %	76.76	20.53	39.02	46.17

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

5. 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 livelihood 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 complexpatterns 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.

6. 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 aresite 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 and to provide more effective land use and land cover information.

References

Achard, F., Eva, H.D., Stibig, H.J., Mayaux, P., Gallego, J., Richards, T., and Malingreau, J.P., 2002. Determination of deforestation rates of the World's humid tropical forests. Science 297: 1999–1002.

Dorren, L.K.A., Maier, B., and Seijmonsbergen, A.C., 2003. Improved Landsat–based forest mapping in steep mountainous terrain using object–based classification. For. Ecol. and Manage 183: 31–46.

Etter, A., McAlpine, C., Wilson, K., Phinn, S., and Possingham, H., 2006. Regional patterns of agricultural land use and deforestation in Colombia. Agriculture, Ecosystems and Environment 114: 369–386.

FAO, 2010. Forest Resource Assessment 2005. Food and Agriculture Organization of United Nations. Rome.

Giri, C., Defourny, P., and Shrestha, S., 2003. Land cover characterization and mapping of continental Southeast Asia using multi–resolution satellite sensor data. Int. J. Remote Sensing 24: 4181–4196.

Ishikawa, M., 2007. Degradation and loss of forest land and land–use changes in Sarawak, east Malaysia: a study of native land use by the Iban. Ecological Research 22: 403–413.

Leimgruber, P., Kelly, D.S., Steininger, M.K., Brunner, J., Mueller, T., and Songer, M.A., 2005. Forest cover change patterns in Myanmar (Burma) 1990–2000. Environmental Conservation 32: 356–364.

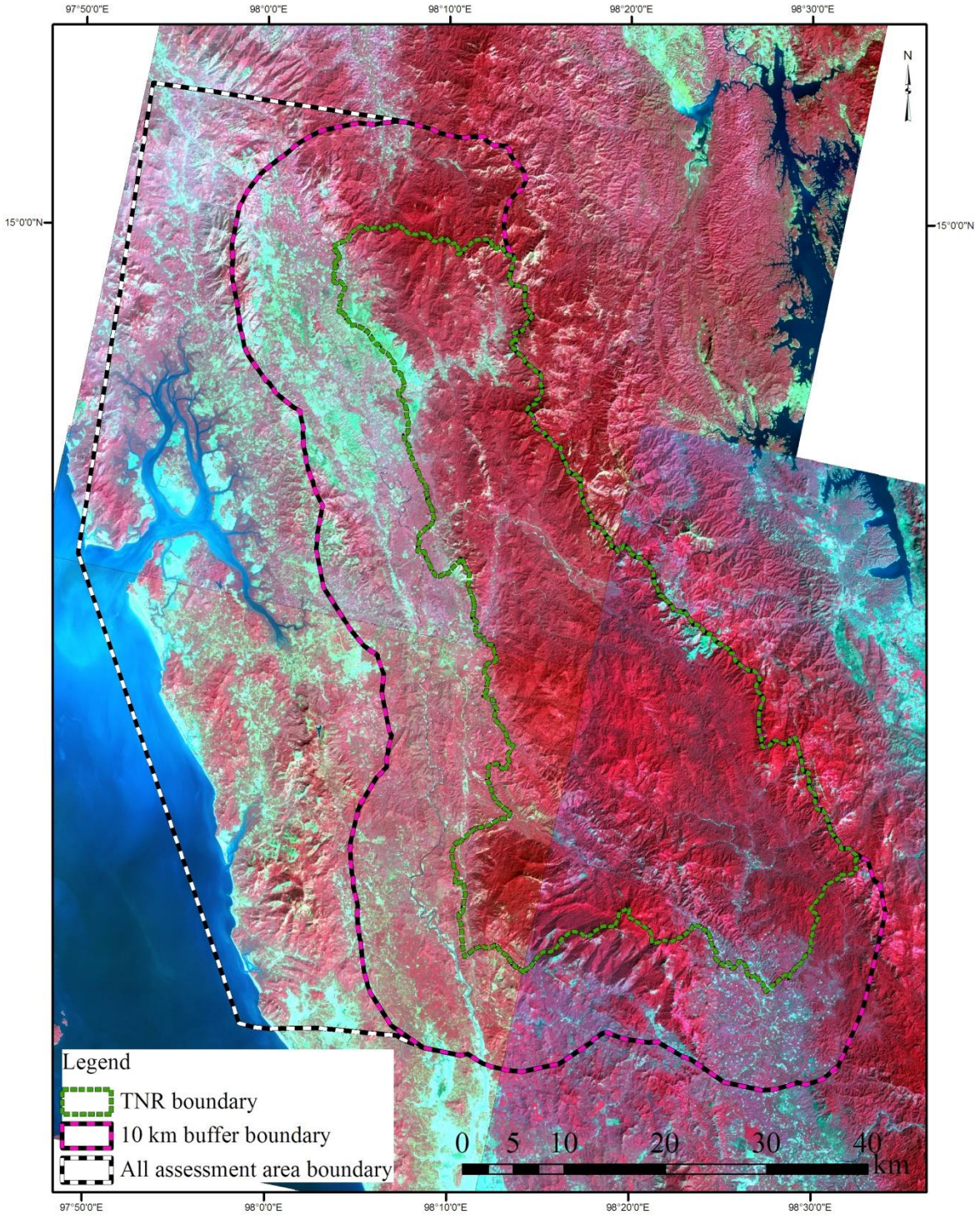
Mon, M.S., Kajisa, T., Mizoue, N. andYoshida, S., 2010, Monitoring deforestation and forest degradation using FCD Mapper in Bago Mountain areas, Myanmar. Journal of Forest Planning, **15**: 63–72.

Olander, L.P., Gibbs, H.K., Steininger, M., Swenson, J.J., and Murray, B.C., 2008. Reference scenarios for deforestation and forest degradation in support of REDD: a review of data and methods. Environ. Res. Lett. 3, doi 10.1088/1748–9326/3/2/025011.

Thapa, R.B., and Murayama, Y., 2009. Urban mapping, accuracy, and image classification: A comparison of multiple approaches in Tsukuba city, Japan. Applied Geography 29: 135–144.

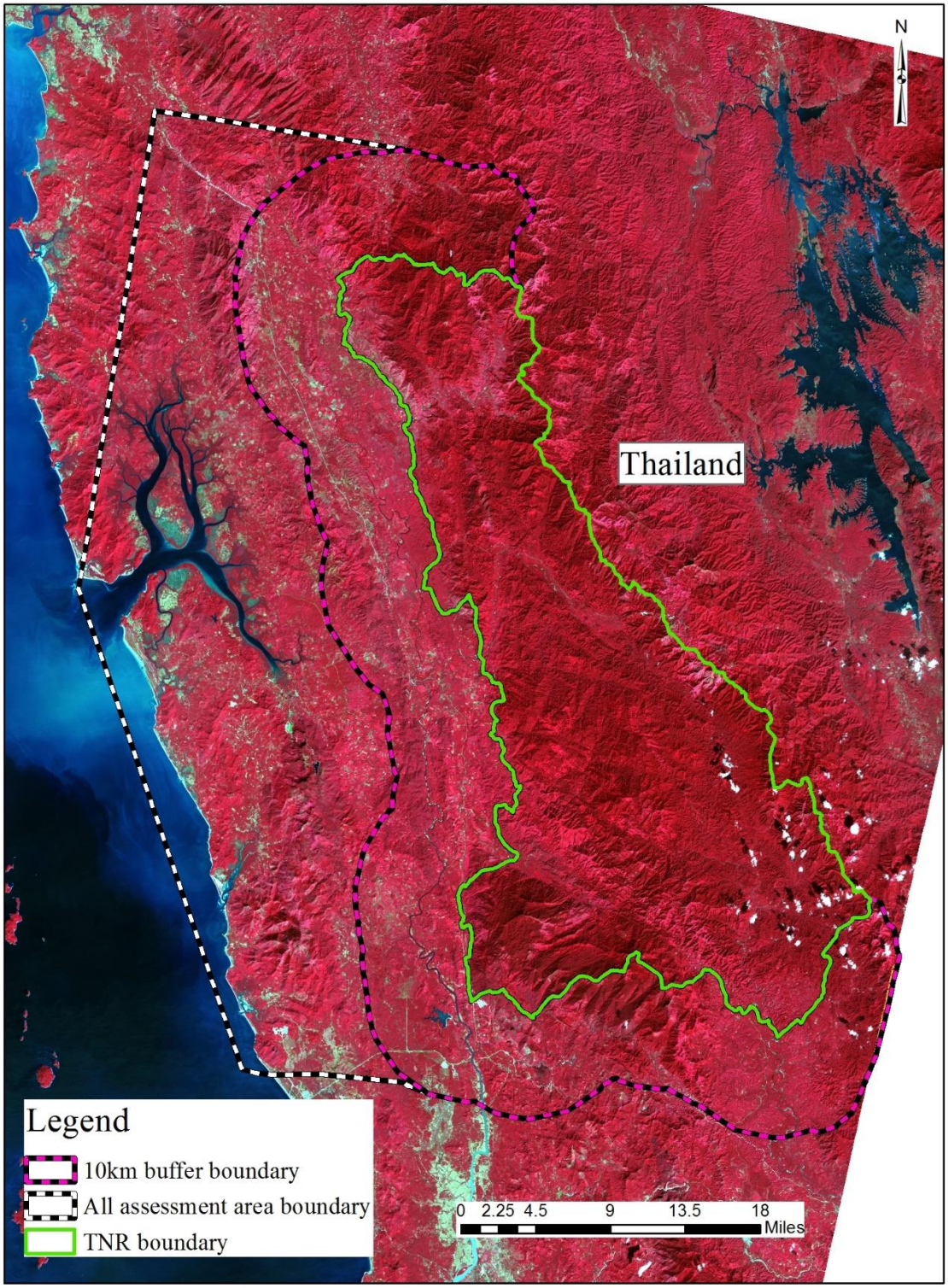
Appendix I

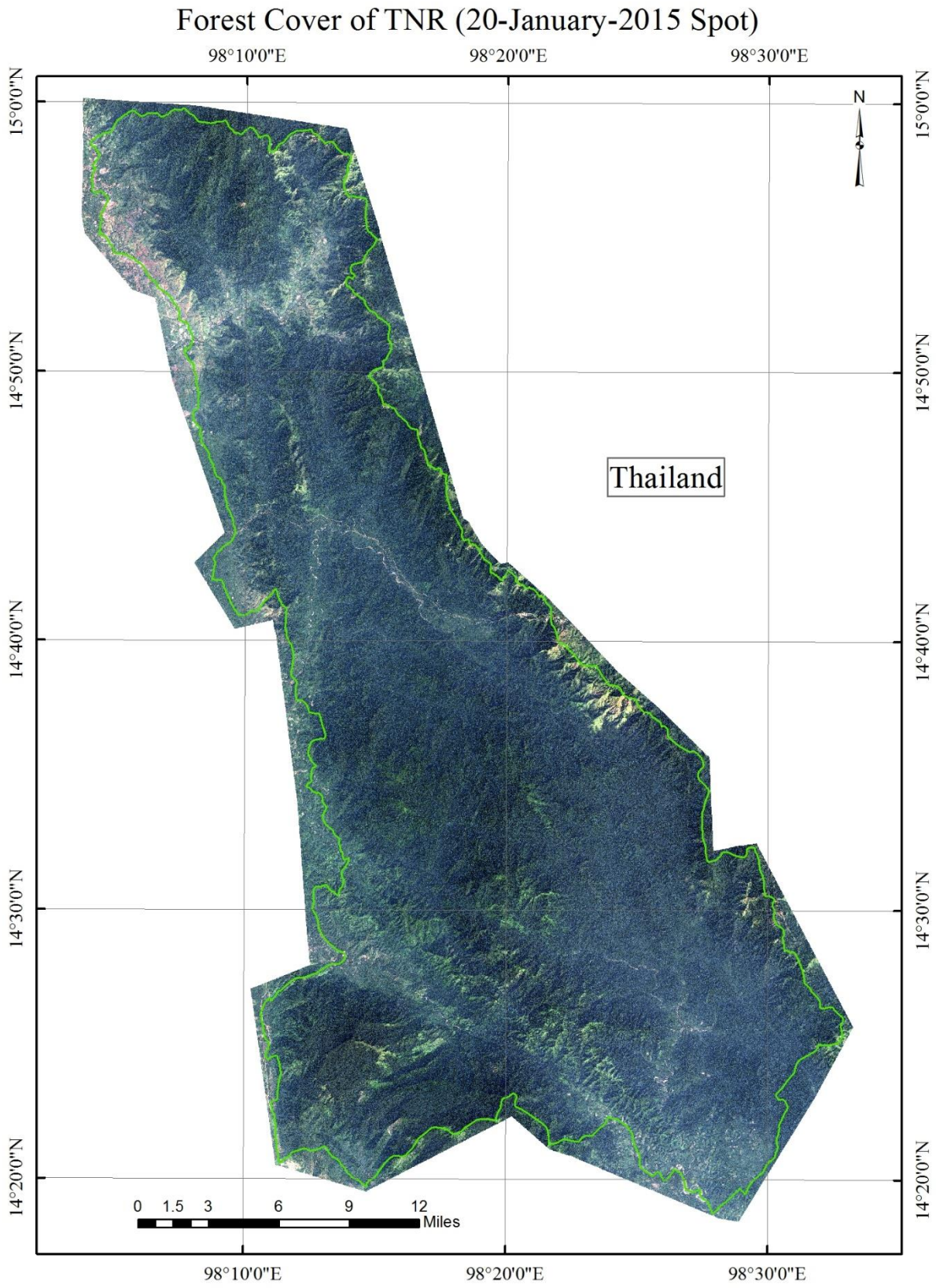
TNR area and its surroundings (2009 and 2010 ALOS satellite imageries)



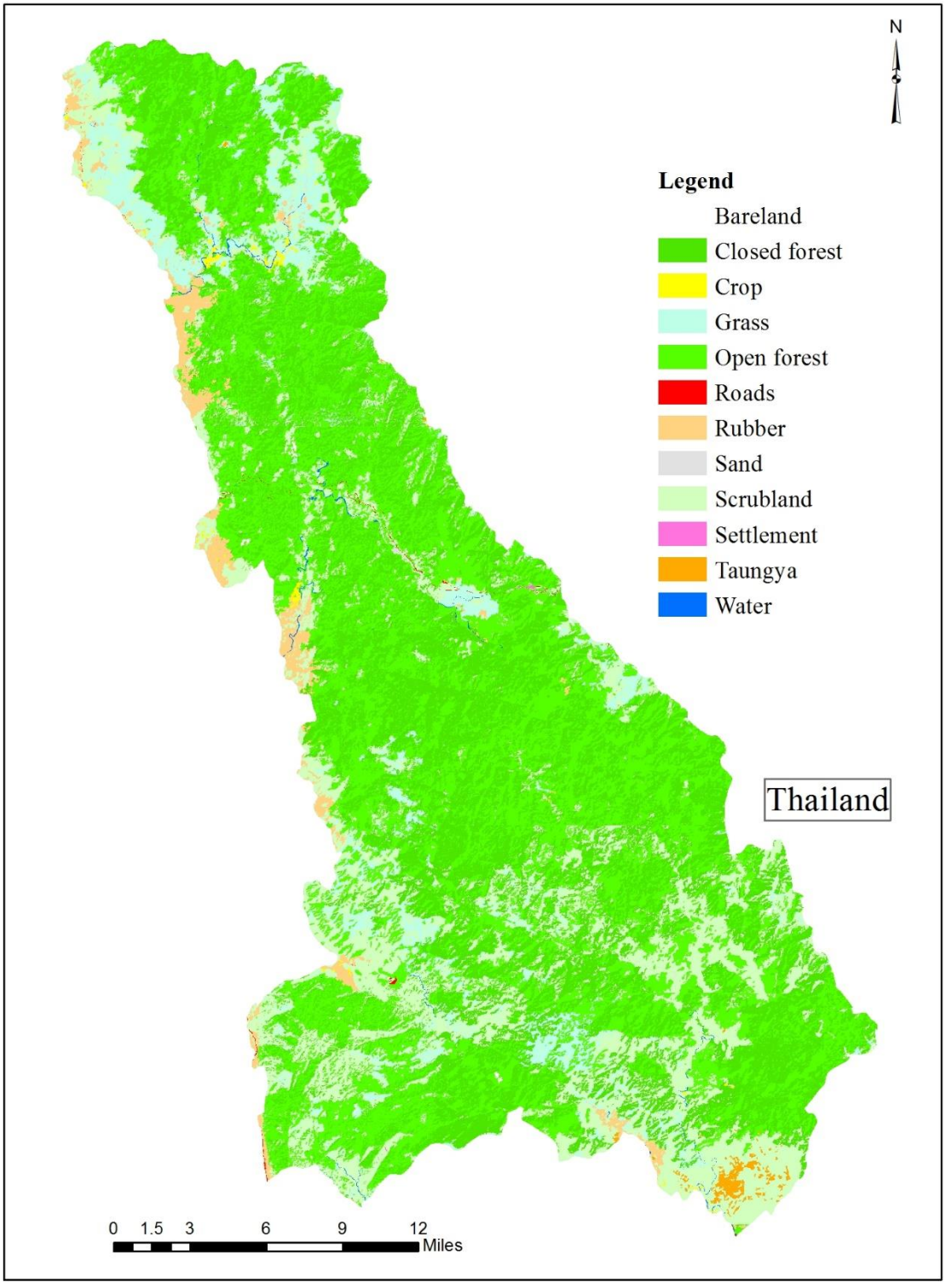
Appendix II

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

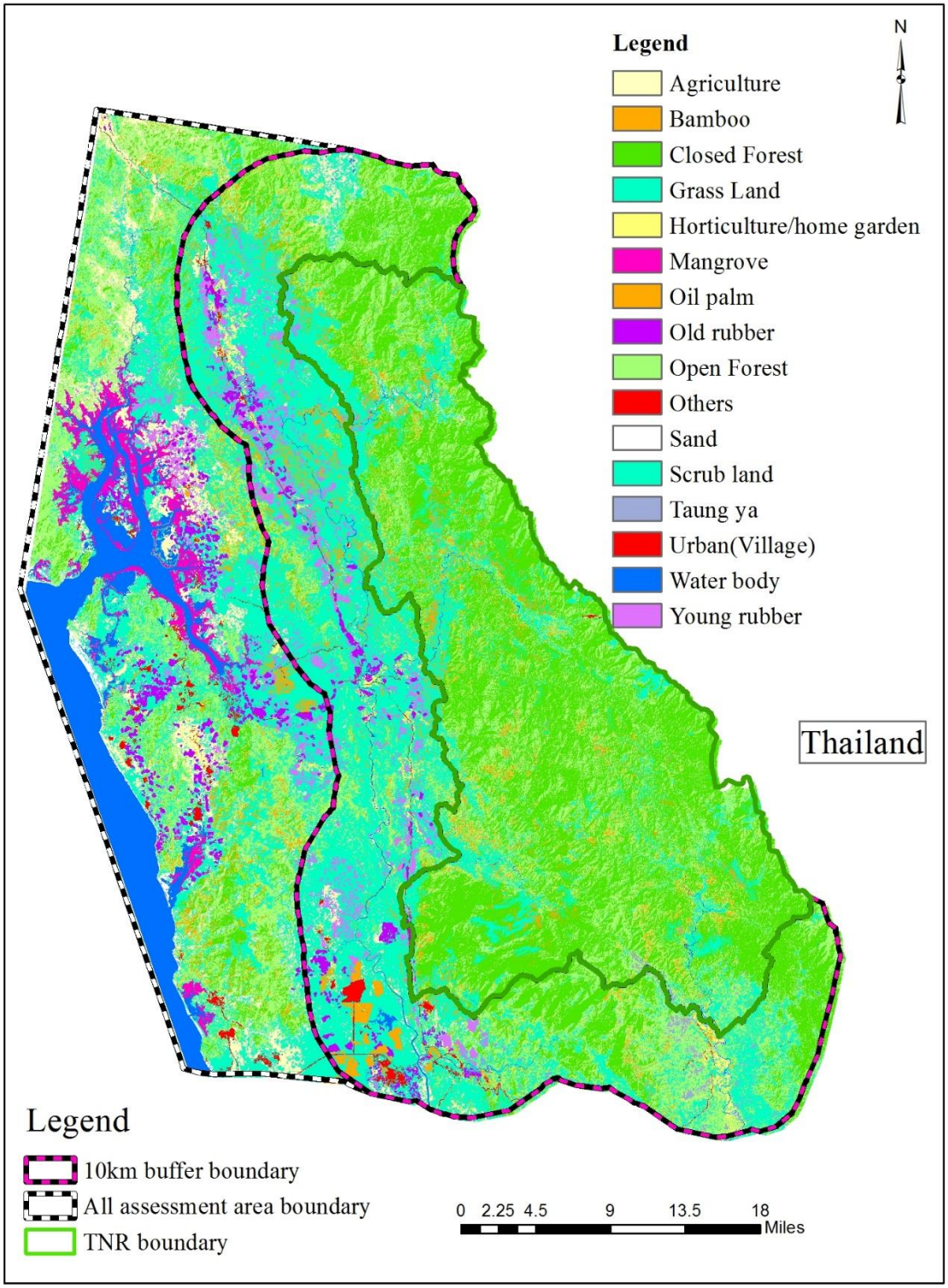



Forest Cover of TNR (20-January-2015 Spot)
98°10'0"E
98°20'0"E
98°30'0"E
15°0'0"N
14°50'0"N
14°40'0"N
14°30'0"N
14°20'0"N
N
Thailand
0 1.5 3 6 9 12
Miles

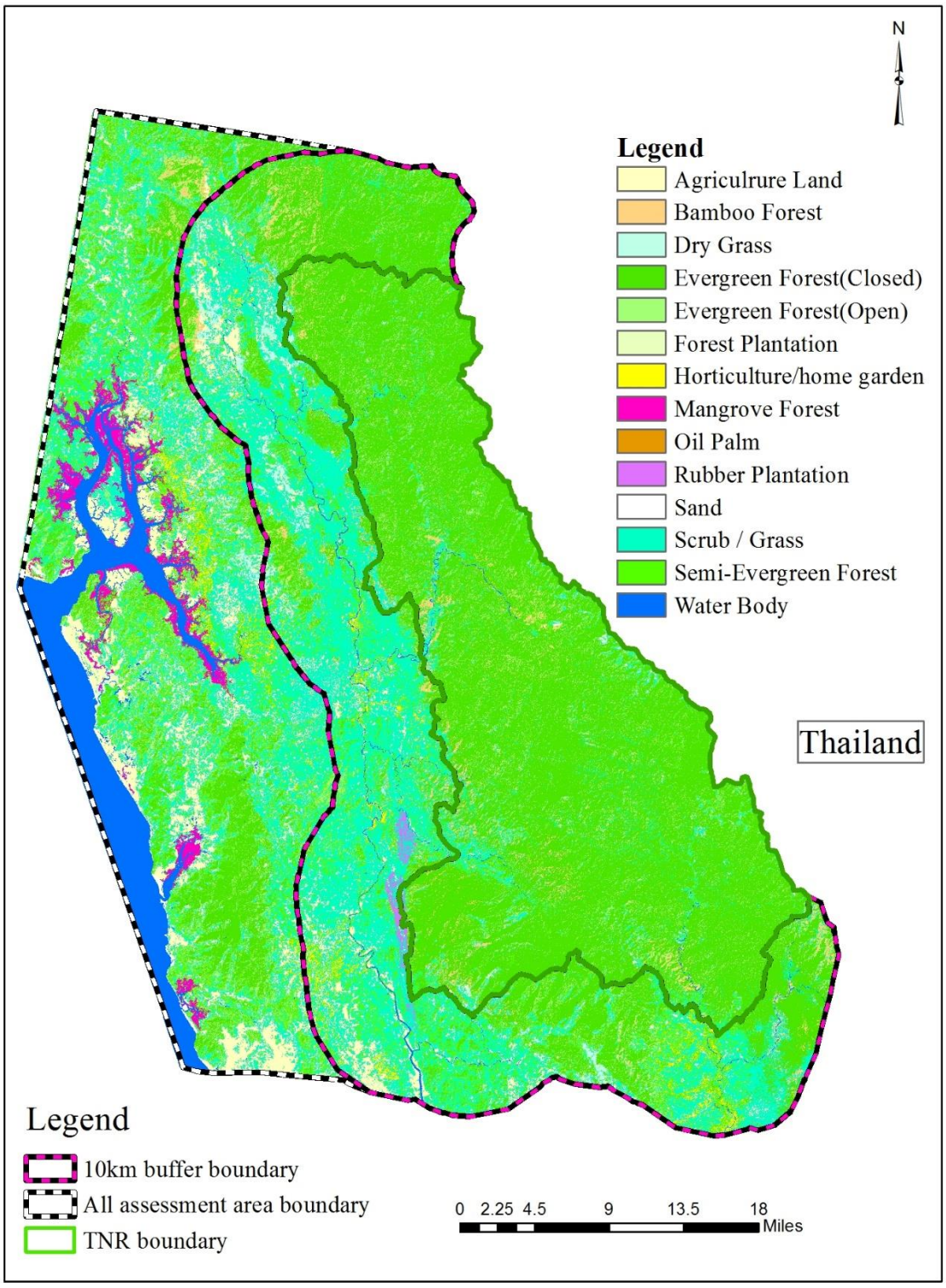
Land Use and Land Cover of TNR area by 2015 Spot 7



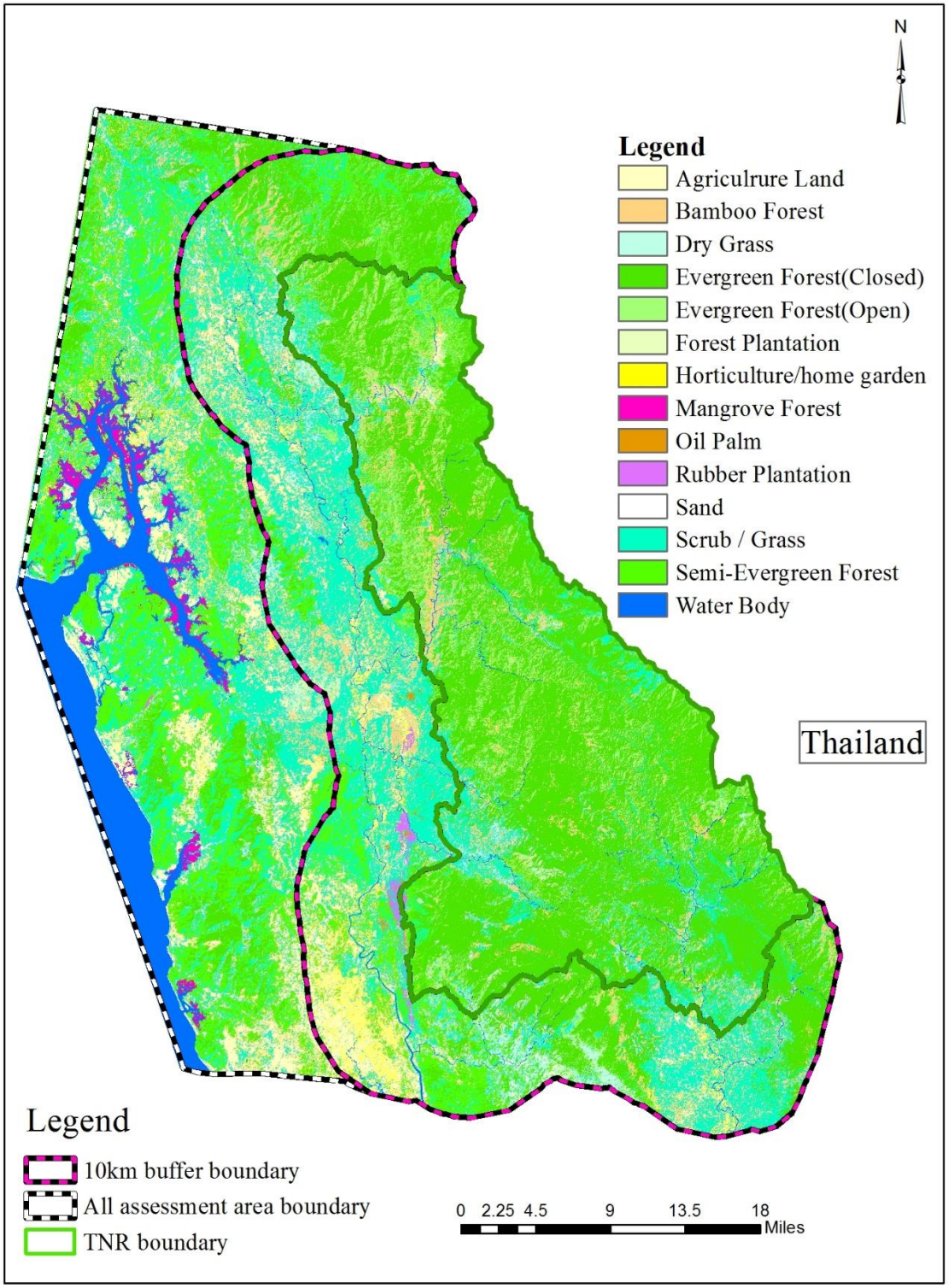
TNR Area and its surroundings (2015)



TNR Area and its surroundings (1990)



TNR Area and its surroundings (2006)



TNR Area and its surroundings (2010)