Forest cover change analysis on a protected area in Southern Myanmar using remote sensing and GIS technique: Applications to forest conservation

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Abstract

As the human population increases in Southern Myanmar, forest area is gradually shrinking and being transformed into other land cover types. This study investigated the forest cover dynamics in the protected area (PA), named as Tanintharyii Nature Reserve (TNR). It has 5 critically endangered species and 5 endangered species, dominated with tropical rainforests. TNR was declared as a PA in 2005 under the management of Myanmar Forest Department (FD), by the financial support of three International Gas Pipeline Companies as compensation for the pipelines' passing through the reserve forest. Firstly, land use/land cover (LULC) maps of study area for the years 1990, 2006, and 2017 were prepared using Landsat data, with eight classes by supervised maximum likelihood classification. The management effectiveness of the PA and a 10-km buffer zone that was created in it was also examined. To acquire the higher accuracy, Google Earth Pro and field validation were conducted during November and December 2017. The results observed that closed forest decreased from 80% in 1990 to 50% in 2017 due to the population increase, settlement encroachment, agricultural land expansion like massive rubber and oil palm plantation, and fruits orchard. Forest degradation increased from −0.41% yr^{-1} before PA (1990-2006) to −0.72% yr^{-1} after PA (2006-2017), and the deforestation rate increased from −0.12% yr-1 before protection (1990-2006) to −0.52% yr-1 after protection (2006-2017) as a result of illegal extraction of natural resources by the local community. When we study within TNR, the average annual forest degradation rate was seriously higher than deforestation. The overall accuracy of the TNR LULC 1990, 2006 and 2017 maps presented 82.6%, 85.2% and 88.2% and Kappa accuracy in 2017 LULC map was the highest, 84.3%. This study clearly discovered that the forest conservation as a protected area can minimize the rate of deforestation better than the rate of forest degradation. The future management of the TNR should emphasize on efficient land use planning, raising the local awareness, initiation the eco-development long-term projects, the establishing of village-owned tree plantations, law enforcement and designating as eco-tourism site.

1. INTRODUCTION

Tropical forests continue to be depleted, both quantitatively and qualitatively, at ever-increasing rates (Hadley, M. and Lanly, 1982; Melillo et al, 1985; Molofsky et al, 1985; Myers, 1980, 1985). The conversion of natural habitat to other land uses is the major driving force

behind worldwide biodiversity loss (Sala et al. 2000). Deforestation is particularly severe in Southeast Asia, such as lowland rain forests, are being destroyed at relative rates that are higher than those of other tropical regions (Achard et al. 2002), due to agricultural expansion, logging, habitat fragmentation and urbanization. The establishment and management of protected areas (PAs) is important in protecting landscapes, achieving biodiversity conservation, and delivering essential ecosystem services (Watson et al 2014). Many local communities, particularly in developing countries, are profoundly dependent on protected areas for energy, employment, and other subsistence needs (Bahuguna 2000). Many protected areas struggle in maintaining and improving their relationship with communities given resource and land-use restrictions, and equivocal governance approaches (Snyman 2012; Djomo Nana and Ngameni Tchamadeu 2014).

In 1990, more than half of the remaining forests in mainland Southeast Asia could be found in Myanmar (Dinerstein et al. 1993). According to the data from Global Forest Resources Assessment (FRA in 2005) indicated 50.2% (FAO 2006), then is rapidly decreasing from about 46.96% in 2010 (FAO 2010) to about 42.92% in 2015 (UN FAO 2015) of the total land area (676,577 km^2). Myanmar's burgeoning populations and high poverty levels have increased pressure on its natural resources and protected areas (PAs, Lwin et al., 1990). Myanmar's protected area (PA) system began nearly 150 years ago under royal patronage (Myint Aung 2007). In Myanmar, Protected Area System (PAS) is administered in accordance with the Protection of Wildlife and Wild Plants and the Conservation of Protected Areas Law (1994) and Myanmar Forest Policy (1995) long run under the Myanmar Forest Department (FD) (FD's Nature and Wildlife Conservation Division, 2017).

As the human population increases in Southern Myanmar, forest area is gradually shrinking and being transformed into other land use land cover (LULC). This research area (Tanintharyii Nature Reserve-TNR) has been experiencing with several threats to forests, especially LULC changes due to massive expansion of agricultural land like subsistence or large-scale permanent fruit orchards, conversion to palm oil and rubber plantation, illegal logging, shifting cultivation and unplanned development project. For example, there still exists minor conflicts for four decades between the ethnic armed groups, national military, and Forest Department.

This study was motivated by the lack of scientific studies on deforestation and forest degradation in this Tanintharyii region. Understanding the rates of deforestation, and spatial and temporal change of forest cover will contribute to plan sustainable forest management and biodiversity conservation. Geographic information system (GIS) integrated with remotely sensed imagery have been successfully employed in establishing and managing protected areas by setting priorities for conservation actions, monitoring conservation targets, and evaluating the effectiveness of conservation strategies. Thus, this study evaluated LULC change by integrating Remote Sensing and GIS, Landsat images and key informant interviews that finds out the determinant factors. The management effectiveness of the PA and a 10-km buffer zone that was created in it was also examined. It mainly focused on forest cover change (namely deforestation) over two decades. The primary purpose of this study is to contribute the scientific information and knowledge essential to policy formulation, biodiversity conservation, land use planning and land resource management.

2. MATERIALS AND METHOD

2.1. Study Area

The study area was selected in a strictly protected area named as Tanintharyii Nature Reserve (TNR) that falls in Yebyu and Dawei Township both within Dawei District, Tanintharyii Region, Southern Myanmar (Fig. 1). It extends approximately 1700 km^2, locates in 14^o 20" N to 14^o 57" N latitude and 98^o 5" E and 98^o 31" E longitude. In north, TNR boundary is adjacent to the Mon State (one kind of ethnicity), and in east, it shares the border with Thailand. It was declared as a strictly natural protected area in 2005 by the financial support of three International Gas pipeline companies, namely, Total, PETRONAS and PTTEPI. These pipelines are exploiting the gas from the sea and transport the gas from offshore sea to Thailand. It is a long-term project (2005-2028), as a compensation financial support. It impacted on forest resources and biodiversity loss along the pipelines because of passing routes across the center of these forest reserves, as a former name. This is the first collaborative project between the Ministry of Natural Resources and Environmental Conservation, represented by Forest Department and three International Corporate for conserving natural resources through the participation of local people (Saw Win & Maung Maung Pyone 2012).

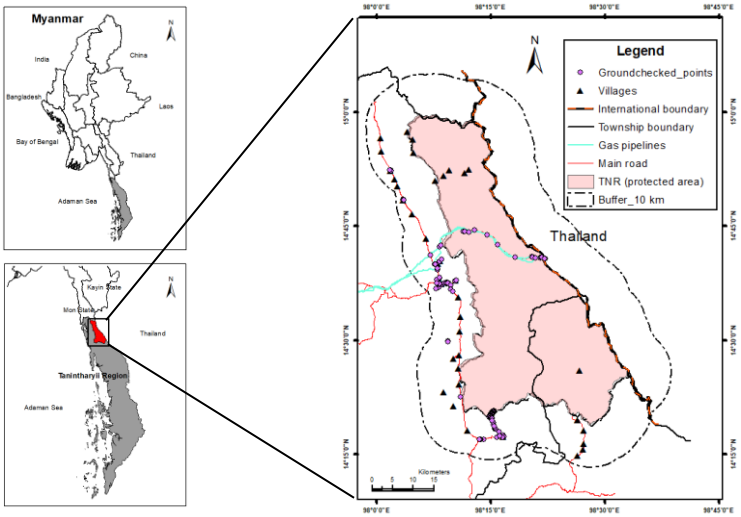


Fig 1. Location of TNR, 10km buffer, ground-truthing points within TNR and Myan-Buffer, three international gas pipelines and villages

The average minimum and maximum temperature are from 13-37 ^{o}C for 10 years (2008-2017). The average annual rainfall is 5363 mm during the period of 10 years (2007-2016) (unpublished official data, Dawei District Forest Department, 2017). The elevation is ranged from 15 m near the seaside to 1400 m alongside of the Thailand boundary. TNR is almost dominated by tropical rain forest in high elevation area, mixed deciduous and bamboo forest in the lowlands. TNR is a biodiversity hotspot area under the management of Forest Department (FD). It has 5 critically endangered species (CR) and 5 endangered species (EN) such as population of Kanyin (Dipterocarpus spp.), Thingan (Hopea spp.), Ban (Anisoptera spp.) and Kaung hmu (Anisoptera scaphula) species belonging to Dipterocarpaceae family or Kanyin pyan (*Dipterocarpus kerrii* King) CR, Kanyin ni (*Dipterocarpus turbinatus* Gaertn. F.) CR, Taung thingan (*Shorea farinosa* Fischer) CR, Kaung hmu (*Anisoptera scaphula* (Roxb.) CR, Kanyin (*Dipterocarous dyeri* Pierre) CR, Kanyin phyu (*Dipterocarpus alatus* Roxb.) EN, Kanyin si (*Dipterocarpus costatus* Gaertn. F.) EN, Kaban/Ban (*Anisoptera costata* Korth.) EN, Ban kaya (*Shorea gratissima* Dyer) EN, Kanyin kyaung che (*Vatica dyeri* King) EN (Thein

2007). There are over 40 villages: 30 villages outside of TNR and 11 villages on or inside TNR in Fig. (1). Population is around 20,845 (unpublished, Township Administration Office, 2017). There is a long history of settlement and four ethnic groups are found settled. Namely, Dawei, Karen, Mon tribes and little Burma were mixed dwelling and migrated Karen and Mon tribes were dominant (unpublished, TNR operational management plan, 2017).

2.2. Data Sources

In this study, three pairs of multi-temporal clear, cloud-free Landsat images were selected over the study area: 1990 (Landsat 5 TM); 2006 (Landsat 5 TM) and 2017 (Landsat-8 OLI & TIRS) (Table.1). All satellite imageries were freely downloaded during the open season from the Earth Explorer Website. Landsat 1990 and 2017 year were being able to acquire the cloud percentage less than 1% (0.01% & 0.03%, 0% & 0%), image quality is 9. In 2006 Landsat, line stripes at the margin of images and partial cloud were found partial cloud (0% & 13%, image quality is 7).

Table 1. Detailed list of applied data in this study

Type/ Resolution	Acquisition Date	Path/ Row	Data Sources	Reasons
Landsat-5 TM (30 meter)	Jan 29th, 1990 Feb 23rd, 1990	130-050, 131-050	USGS Earth Explorer	Classification
Landsat-5 TM (30 meter)	Feb 10th, 2006 Mar 07th, 2006			
Landsat 8 OLI_ TIRS (30 meter)	Jan 23rd, 2017 Feb 1st, 2017			
Sentinel-2	Feb 9th, 2017	3- Imagery	USGS Earth Explorer	Validation 2017 map classification
ALOS AVNIR-2	Dec 10th, 2008	ALAV2A 153323300	Forest Department	Validation 2006 map classification
ASTER GDEM-2	October, 2011	3- Imagery	USGS Earth Explorer	Elevation check
Google Earth Imageries			Google Earth Pro	Validation for three periods
Topo and historical Maps (Secondary)	1945, 2010 & 2015		Forest Department	Validation for three periods

2.3. Image Classification

After being downloaded the satellite images, preprocessing stage such as radiometric calibration and atmosphere corrections, mosaicking, image enhancement was carried out by using the ENVI 5.5 software package (Resources 1976). Then, maximum likelihood classification, one of the most popular supervised classification method (Al-Ahmadi & Hames, 2009), was applied to images acquired in 1990, 2006 and 2017, respectively (Mondal and Southworth 2010). The color, tone, shape, size, texture, shadow, association and pattern of the objects mainly was determined and distinguished on visual interpretation based on researcher's remote sensing interpretation experiences(Resources 1976, Fundamentals of remote sensing, pages 144-146), and defined the training samples (approximately 200-300 for each LULC) over the eight LULC categories,(FAO FRA 2012) as shown in Table 2. For our objectives, we

created 10 km buffer area outside of TNR(Mondal and Southworth 2010) from TNR boundary, not only Myanmar area but also within Thailand (Fig.1).

Table 2. Definition of LULC categories with FAO definitions

	LULC class	Description
1	Closed Forest	>40% (canopy cover)
2	Open Forest	10-40% (canopy cover)
3	Other Wooded Land	< 10% (canopy cover)
4	Scrubland	Lower shrubs, thatch
5	Grassland	Green and dry grass, grazing land
6	Water	Permanent open water, streams, rivers, reservoirs
7	Agricultural Land	Crop land, cultivable land, orchard, rubber/ palm oil plantation
8	Others	Settlement, bare land, rocky, transportation

2.4. Data collections

To acquire the high accuracy, the field validation was conducted on November and December 2017 by using over 400 GNSS points that already georeferenced WGS1984, to differentiate the defined eight categories (1) within buffer and (2) inside PA (Fig.1). During survey, the geo-tagged photos were recorded, ground observations, basically, the historical baseline information about TNR was explored. Semi-structured questionnaires were manipulated for key informant interviews with 51 people: TNR project staff (20), some village heads (20), non-government regional staff (3), and institutional local staff (8) to discover the local livelihood pattern such as shifting cultivation during 1990 and 2006, 2017, income source, education level, living standard, impacts of pipeline construction activities, the regional issues, threats to natural forests management, forest and agricultural plantations. This study conveyed literature review; for example, international papers and FD and TNR project national reports such as floral survey, socio-economic survey, operational management plan, etc.

2.5. Post-classification

Post-classification process was carried out in classification; (1) majority filter, (2) accuracy assessment by using ArcMap (10.5) and Envi (5.3) and Google Earth Pro software. The Kappa Coefficient was used as one of the most common means of expressing classification accuracy, then, the stratified random sampling points were employed based on the eight LULC classes Eq. (1) (UTSA, n.d.). Based on multinomial probability theory:

$$N = \frac{B\Pi_i(1-\Pi_i)}{b_i^2} \qquad \text{Eq. (1)}$$

Is the proportion of a population in the i^{th} class out of k classes that has the proportion closest to 50%, b_i is the desired precision for this class, B is the upper $(\propto/k) * 100\ th$ percentile of the chi square x^2 $(x2)$ distribution with 1 degree of freedom, and k is the number of classes? From this above formula calculation, the stratified random points were carried out for accuracy assessment, such as 736 (in 2017 year) (e.g., closed forest-292, open forest-83, other wooded land-39, scrubland-47, grassland-47, water-9, agricultural land-203, others-9), 736 (in 2006 year), 747 (in 1990 year), respectively, and verified with Sentinel2, ALOS imagery and Google Earth image.

2.6. Deforestation and forest degradation analysis

Definitions and rules used to calculate deforestation and forest degradation between the periods; 1990-2006, 2006-2017 and 1990-2017 are explained in Table 3.

Forest cover and deforestation rates were calculated for the sub-time step datasets using the standardized approach proposed by Puyravaud, (2003).

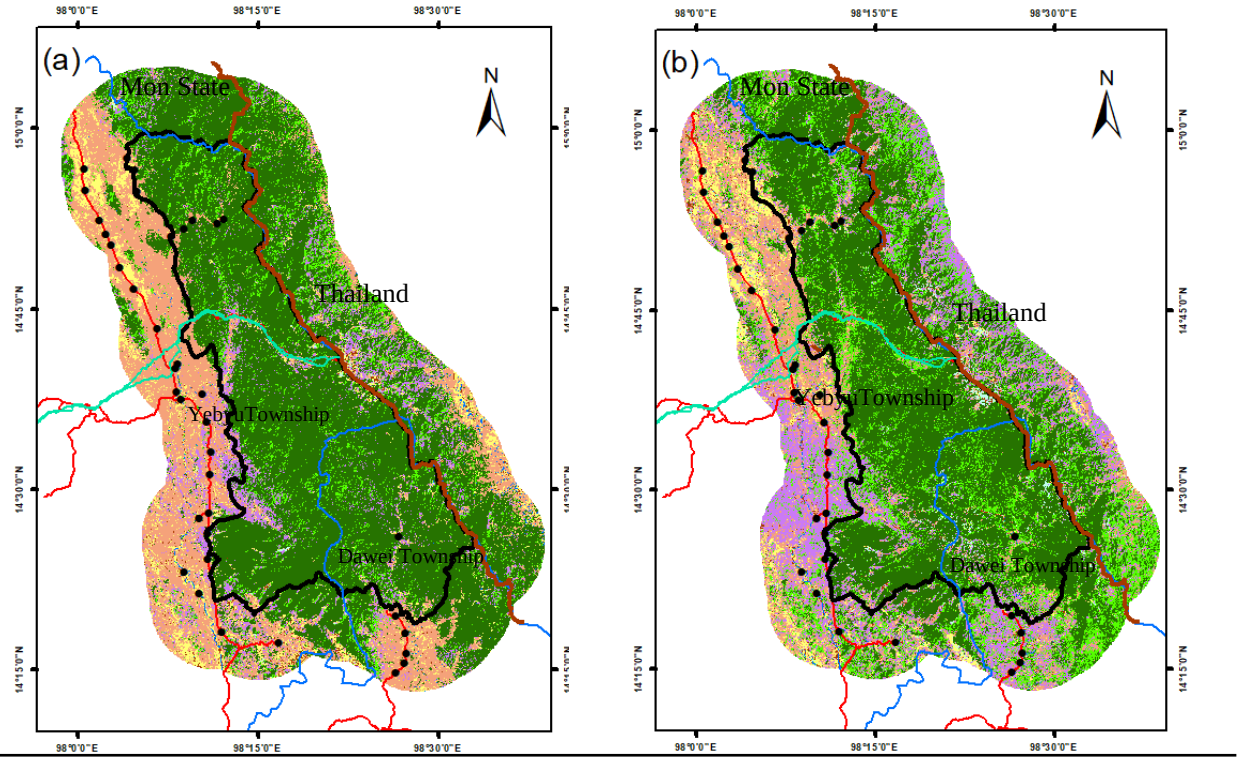
Table 3. Definitions and rules used to calculate deforestation and forest degradation

Change types	Definition and calculation of changes
Deforestation	complete conversion of forest to non-forest
Gross forest degradation	closed forest to open forest (Uryu et al. 2008)
Annual rate of net deforestation (%)	$\frac{net\ deforestaion}{total\ forest\ areas\ at\ initial\ year\ of\ assessment} * \frac{1}{assessment\ periods} * 100$
Annual rate of net forest degradation (%)	$\frac{net\ forest\ degradation}{total\ forest\ areas\ at\ initial\ year\ of\ assessment} * \frac{1}{assessment\ periods} * 100$

3. RESULTS

3.1. Distribution of LULC inside TNR

There are numerous changes over time, and different location. The dominant land-use and land-cover class for all three maps were forest including both, two forest categories (closed forest- 81% in 1990, 70% in 2006 and 58% in 2017) and open forest (8% in 1990, 15% in 2006 and 16% in 2017) within TNR (Table 4 and Fig 2). Agricultural land changed over time, at the former times, existed stably at 2% in 1990, 1% in 2006 and dramatically increased up to 11% in 2017 (Table 4). During the period of 27 years, closed forest moderately transformed to open forest and transformed to degraded vegetation (combined with wooded land, scrub land and grassland) and agricultural land category (Fig 2).



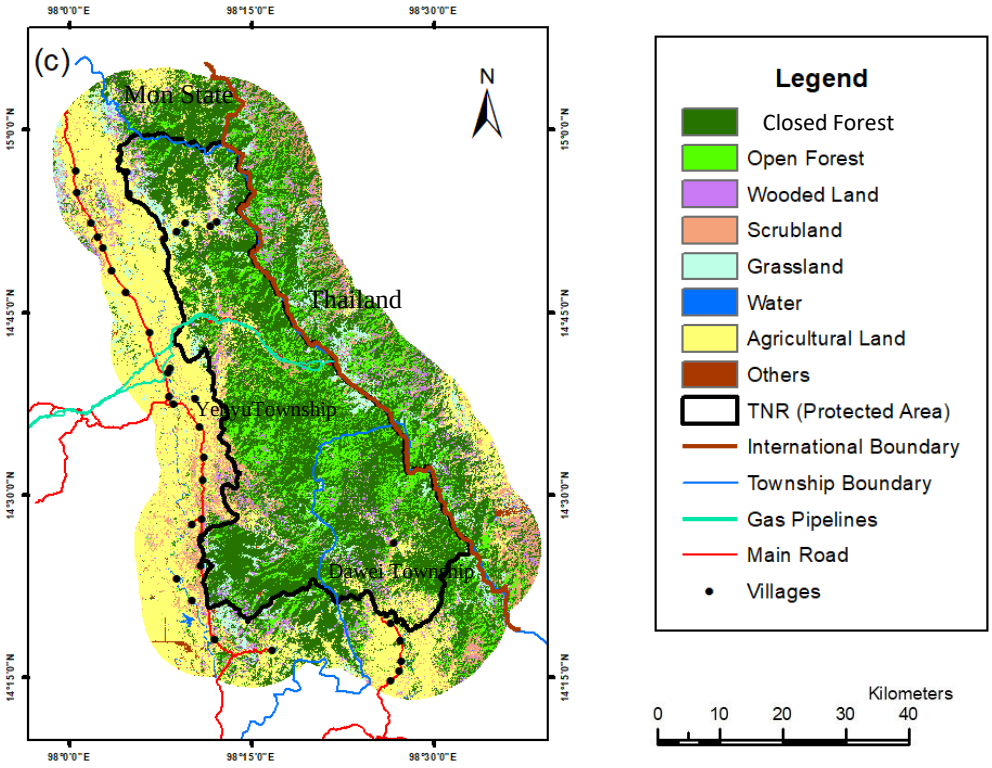


Fig.2. LULC Maps that was derived Landsat imageries within the protected area and 10 km buffer: (a) in 1990, (b) in 2006 and (c) in 2017

In 1990 classify image, there is less area of agriculture and settlement (Fig 2a). However, we found the forest degradation, named as open forest, wooded land, and scrubland near the boundary of TNR. Gradually, open forest area became expand about two times from 8.11% in 1990 to 15.59% in 2006 (Table 4). Starting from 2006 thematic maps, the forest was suffered degradation surrounding the pipeline routes and low elevation area (Fig 2b). Further, large area of wooded land was occurred increase, particularly nearby the settled villages. Moreover, it was serious in the north and south part of TNR. Gradually, wooded land changed to the scrub land over time. The scrub can be observed in the north part of TNR in 2006, eventually, both categories such as wooded land and scrubland transformed to the agricultural land near the villages and low elevation area in 2017 (Fig 2c).

3.2. Distribution of LULC within Myanmar buffer

Within Myanmar buffer zone, the dominant categories were scrub land (45% in 1990) in the first period, before protection. Other side, wooded land (8% in 1990 up to 23% in 2006) were regained and scrub land decreased from 45% in 1990 to 25% in 2006 year, assumed by the activities of natural growth pattern. During the three periods, agricultural land existed 12% in the whole area of Myanmar Buffer (MB) in 1990 and decreased to 10% in 2006, then, seriously rose to 56% in 2017, given in Table 4 and Fig 2 and 3. At first, agricultural land was mostly found in the north and south part outside TNR, Fig (2a).

The dominant category is scrub land in 1990, it might be resulted from shifting cultivation. It was replaced by the wooded land, as fallow land, because of natural regeneration pattern, distinctly, at the south part adjacent to the pipelines across that is hillside area.

According to 2017 LULC map, after a long time, most of the degraded vegetation was finally converted to the agricultural land within 10-km buffer inside Myanmar, particularly, along the main road and lowland area. On the other hand, other category like urban area was distinctly appeared in the southern part of TNR buffer, Fig 2c.

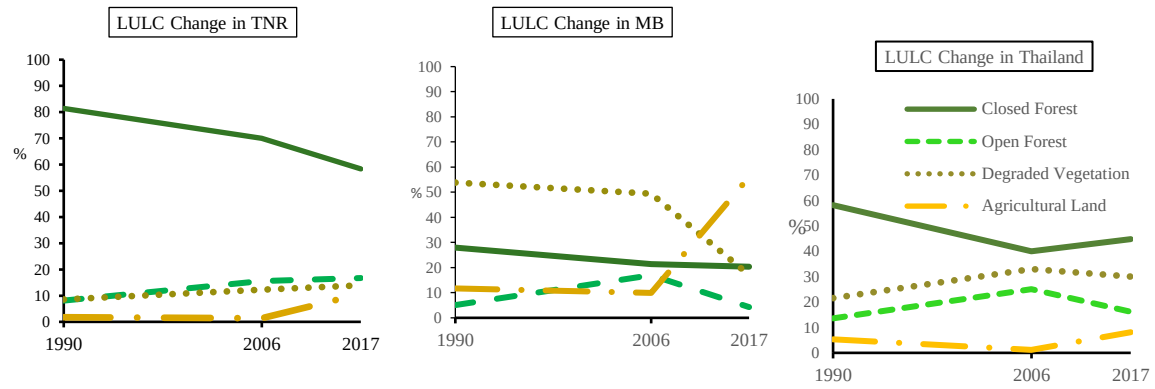


Fig.3. Situations on LULC Change during the whole study period within the protected area and 10 km buffer: (a) in 1990, (b) in 2006 and (c) in 2017

Outside of TNR in 1990, most area of northern part that was located inside Mon State was covered with closed forest. In addition, some parts of south part within Buffer, that is falling into the different township called as Dawei Township, were still covered with forest. During the second period, there is seriously change of LULC in northern and southern part of buffer, located in Mon and Dawei area, Fig 2b. At the time of protection in 2006, LULC categories within Myanmar buffer zone were proportionally distributed from the largest percentage of each category (scrub- 25%, wooded land- 23%, closed forest- 21% and open forest- 17%), Table 4.

From 2017 classified results, we found that closed forest remained the stable conditions by expressing the area percentage (21% in 2006 and 20% in 2017), however, naturally preserved in different locations over time. Eventually, we observed that open forest and degraded vegetation, such as wooded land and scrubland altered to agricultural land after being protected for 11 years, illustrated in Fig 2c.

Table 4. Comparison of LULC change in 1990, 2006 and 2017 year by three zones (TNR, Myanmar Buffer and Thailand Buffer) described as (ha and %)

Year		Closed Forest	Open Forest	Wooded Land	Scrub land	Grass land	Water	Agricultural Land	Others
1990	TNR (ha)	131147	13061	8328	5197	243	62	2866	187
	%	81.41	8.11	5.17	3.23	0.15	0.04	1.78	0.12
	Myan-Buffer (ha)	46573	8433	14032	75387	267	755	19526	1625
	%	27.96	5.06	8.42	45.25	0.16	0.45	11.72	0.98
	Thai Buffer (ha)	53020	12394	9364	10039	256	712	4811	557
	%	58.17	13.60	10.27	11.01	0.28	0.78	5.28	0.61
2006	TNR (ha)	112751	25108	9178	7666	2954	196	2223	1011
	%	69.99	15.59	5.70	4.76	1.83	0.12	1.38	0.63
	Myan-Buffer (ha)	35605	28253	38954	41524	1741	887	16528	3004

	%	21.38	16.97	23.40	24.94	1.05	0.53	9.93	1.80
	Thai Buffer (ha)	36443	22854	20771	7736	1564	176	1074	505
	%	39.99	25.08	22.79	8.49	1.72	0.19	1.18	0.55
2017	TNR (ha)	93989	26910	7377	5097	9964	240	17163	349
	%	58.35	16.71	4.58	3.16	6.19	0.15	10.65	0.22
	Myan-Buffer (ha)	33906	7126	7705	11167	9536	1389	93416	2329
	%	20.35	4.28	4.63	6.70	5.72	0.83	56.08	1.40
	Thai Buffer (ha)	40816	14723	8069	11369	7987	153	7409	605
	%	44.79	16.16	8.85	12.48	8.76	0.17	8.13	0.66

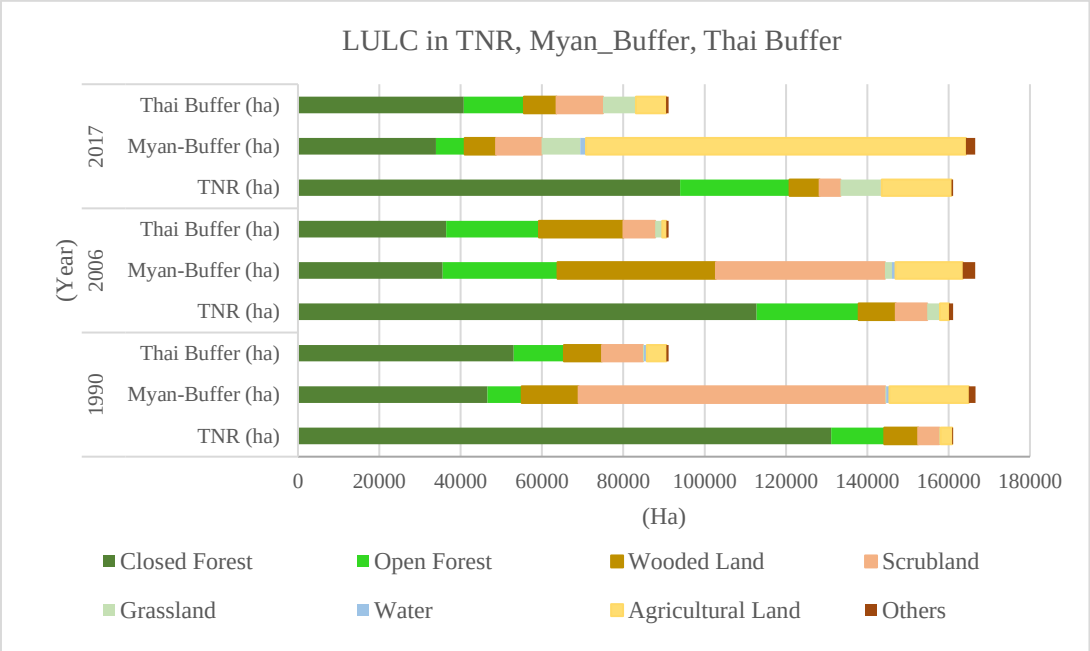


Fig 4. Comparison of LULC change in 1990, 2006 and 2017 year by three zones (TNR, Myanmar Buffer and Thailand Buffer) described as (ha and %)

3.3. Deforestation and forest degradation rates

Firstly, when we look up the calculated results on protected area as shown in Table 5, the deforestation rate (-0.52%) after protection was greater than the rate (-0.12) before protection, shown in Table 5. Similarly, the forest degradation rate is steadily higher than the deforestation rate at the time of before and after protected situation both. Outside TNR, within Myanmar buffer area, the study observed the condition of reforestation, that means natural regrowth pattern, (0.4%) was attained during the first period. The tremendous forest clearing to another LULC, that means deforestation (-1.75%) was found during the second period (2006-2017), after the protected area was being established and gas pipelines project initiated.

During the time of 27 years, the mean annual deforestation rate (-0.28) experienced lower than the forest degradation rate (-0.54), Table 5. Throughout the time of 27 years, the mean annual deforestation rate was higher within buffer than inside TNR, nevertheless, the

mean annual forest degraded rate inside TNR was greater than outside TNR, protected area. Comparing the results outside and inside the protected area, the area outside TNR experienced the greater forest degradation during 1990-2006, highest deforestation rate (-1.75) was occurred during 2006-2017.

Table 5. Rates of deforestation and forest degradation inside PA (TNR) and within MB

Location	Study period	Def_rate yr^{-1}	Deg_rate yr^{-1}
1. TNR, PA	1990-2006	-0.12	-0.41
	2006-2017	-0.52	-0.72
	1990-2017	-0.28	-0.54
2. MB	1990-2006	0.40	-0.73
	2006-2017	-1.75	-0.19
	1990-2017	-0.47	-0.51

3.4. Accuracy assessment

The overall accuracy of the LULC maps within TNR in 1990, 2006 and 2017 presented 82.6%, 85.2% and 88.2% and Kappa coefficient of classification image dated 2017 was 84.3%. It is high compared to other images of 2006 and 2017 were 80.1%, 74.8%, respectively, as shown in Table 6.

Table 6. Summary of classification accuracies (%) for 1990, 2006 and 2017

LULC class	1990		2006		2017	
	Producer's	User's	Producer's	User's	Producer's	User's
Closed Forest	98.9	86.5	97.6	89.9	98.5	91.1
Open Forest	43.8	78.0	76.5	78.2	71.4	95.2
Other Wooded Land	69.7	83.6	78.7	84.0	51.5	85.0
Scrubland	93.2	79.0	89.2	76.3	80.9	79.2
Grassland	80.0	80.0	100.0	90.9	95.5	87.5
Water	83.3	50.0	100.0	100.0	100.0	40.0
Agricultural Land	51.5	74.5	52.9	94.7	95.7	87.3
Others	80.0	80.0	77.8	70.0	100.0	70.0
Overall accuracy	82.6		85.2		88.2	
Kappa statistic	74.8		80.2		84.3	

4. DISCUSSION

4.1. Classification accuracy

The area of land use or land cover change obtained directly from a map may differ greatly from the true area of change because of map classification error. The high accuracy in 2017 LULC map was acquired with the aid of ground truth points and various ancillary data. The low accuracy means that there is no ground truth data that belong to the images in 2006 and 1990. Particularly, the Landsat_5TM images 1990 were not vivid with the lack of reliable historical data. Moreover, some difficulties were faced when open forest and perennial old plantations were distinguished due to the similar spectral reflectance emitted from them. Hence, during the field survey, we observed that the areas classified as shrub also included young rubber plantation and open forest also included old rubber, oil palm plantations in 2006 LULC map. It

is because the crown patterns of rubber plantation and shrub forest were similar to each other and sometimes they are mixed spectral reflectance with each other (Like, Boundeth & et al, 2012).

4.2. LULC change inside TNR

In this study, the results revealed that there is a considerable change in forest cover at a faster pace. Different situations that influenced on LULC dynamics were occurred on the location. Closed forest was potentially fragmented as the form of open forest, that was legally and illegally logged during the time of 27 years.

In 1988, Ministry of forestry created income from the natural resource extraction, for granting the logging activities to the national and international private companies both. They granted contracts to foreign companies, Thailand companies. It improved access to virtually undisturbed forest areas in the Tanintharyii Mountain Range running along the Myanmar-Thai border(Taninthayi Nature Reserve Project 2013). The resulting regular transports of logs to Thailand provided opportunities legal and illegal trade in wildlife and forestry products as well. However, in 1996, the Myanmar Government ceased allowing Thai logging companies to continue logging in Myanmar due to gross violations by clear-cutting and logging outside designated areas as well as exporting more timber than was specified number (Seatec International, 1999). According to the Forest Law (1992), it was stated that forest products may be extracted for domestic or agricultural or piscatorial use and not for commercial scale by local people. Normally, local people near TNR extract small-sized timber for house buildings and furniture making. Local people now use chainsaws not only for felling and logging but also for sawing timber (Tin Swe 2008). According to the key informant interview, FD staff could not terminate the commercial scale of illegal logging that was generated by the intruders, outsiders and settled indigenous armed society.

At the location of high elevation and steep slope, closed forest distinctly remained, and natural regrowth was excellent. In low elevation, forests are mostly degraded and transformed to another land use. Slope has been a distinct factor affecting the spatial pattern of village expansion. Generally, people prefer to live on flat or gentle terrain (Estoque and Murayama 2011). Owing to the fact that the number of 9 villages colonized in the north part of TNR by indigenous Mon people, named as ‘Mon Pyi Thit’ area. Since 1995, these villages are located inside northern TNR. As a result, the obvious settlement of 9 villages on the periphery utilize forest products for substantial use and fruits orchard establishment inside TNR, which owing to their greater human populations (Taninthayi Nature Reserve Project 2013). On the other side, the detrimental impacts on the forest, particularly forest degradation was also observed seriously at the middle part of protected area. There is still evidence of shifting cultivations/ orchards particularly in the northern and southern parts of TNR up to 2010 (Taninthayii Nature Reserve Project 2015). Beside this, we noticed from the results of field observations that these ethnic villagers’ practice as orchard-based shifting cultivation and extraction of forest resources: felling timber and NTFP for substantial use and commercial selling.

Further, we noticed from key informant interviews and observation that ethnic people mainly operated the logging activities with some buffaloes and using river route for carrying the drifted timber. In the PA patrolling case, when the project staff and forest department investigated any sign or information relevance with the prohibited timber extraction, encroachment, in-migration activities, they cannot fully control or halt such kind of activities because some of them who are local forces firmly hold the guns. In the case of arresting the

felled logs or anybody with illegal logs, forest department staff are unexpectedly being suffered from the attack of the illegal logging association due to guns-holding of two ethnic groups and human dwelling inside the PA. Hence, there still exists minor conflicts that come from various kinds of impacts between conservation efforts of forest department and resource extraction of local community, and dependence of ethnic armed society on forest.

In the interior part of TNR, driving forces leading to deterioration of natural forests were non-identical in southern part and northern part due to individual preferences and customs of ethnicities. Northern part was mostly suffered by deforestation, for example, agricultural expansion. Middle part was damaged by the gas pipelines construction and agricultural encroachment near TNR boundary due to unclear boundary and less knowledge of local people concerned with TNR boundary demarcation. Ethnicity in TNR south part rely on forest resources, both agriculture and illegal logging because timber extraction is the fastest way for these communities to realize rapid profits, like (Myint Aung 2007).

4.3. Deforestation and Forest degradation within TNR and MB

To examine the management effective of PA, this study spatially and temporally investigated the deforestation and degradation analysis to compare the forest situation. According to the results of LULC change classification, one important finding of this study was that, within PA and their surroundings, they similarly experienced situation of deforestation and forest degradation on different spatial and temporal scale. According to the analysis results, deforestation rate inside TNR was remarkably lesser than any rate outside TNR. However, we discovered the appearance of forest degradation within TNR. It was continuously increased from (-0.41) to (-0.72) in the second period (2006-2017) even though it was conserved and monitored as a naturally protected area with pipelines project's financial support.

This study found that forest degradation rates within TNR PA were greater than deforestation at any time, similarly these studies in Myanmar Popa Mountain Park (PMP) (Htun et al. 2009) and Bago Mountain area (Mon et al. 2010). After being protected, the rates of deforestation (-0.52) and forest degradation inside PA (-0.72) was greater than any rate (-0.12) and (-0.41) before being notified as a protected area. Inside TNR, closed forests were seriously deteriorated and formed as open forest due to the human disturbances, subsequently, transformed to non-forest categories with the conservation weakness. At last, non-forest categories periodically changed each other over time. Forest cover was mainly remained and untouchable at inaccessible area, eg, steep slope. This finding approved that the LULC change was highly experienced at the level of the low elevation alongside the main road, near the river and surrounding the human settlement area.

During the time of 27 years, the three major threats bringing about LULC change are (1) commercial illegal logging because of the results from higher degradation rates in TNR and interviews, (2) huge expansion of agricultural land by the activities of two ethnic armed groups according to the results of higher deforestation rates at MB in the second period, and (3) pipelines construction due to the forest clearing along the huge pipelines. In local circumstances, local people hugely practiced in shifting cultivation before TNR project initiating. Moreover, forest cover could not be maintained at a stable condition. For many reasons, the natural resources management strategies of TNR project that was monitored by FD is still weak and less effective on forest conservation.

5. CONCLUSIONS AND RECOMMENDATIONS

This study revealed spatial and temporal change of LULC, comparison analysis inside the protected area and their surroundings. Remote sensing and GIS techniques were applied to clarify LULC change, focusing on forest loss, moreover, field observations data were both integrated to investigate the current and historical LULC information. By creating 10-km buffer starting from the boundary of protected area, the management effectiveness of protected area was analyzed in the comparison of forest cover change inside and outside a protected area, Southern Myanmar.

This research discovered the forest conservation as a protected area will be lesser the conversion of forest to another land use (deforestation). The appearance of forest degradation was higher within TNR, even though it was conserved and monitored as a naturally protected area with pipelines project's financial support. Despite being a protected area, deforestation and forest degradation increased both. Hence, it concluded the resources management strategies of TNR project that was monitored by FD is still weak and less effective on forest conservation. When we conserve and manage the natural forest, Myanmar FD should manage the forest conservation activities based on the different results and situations inside and outside TNR. The future management of the TNR should emphasize on efficient land use planning, raising the local awareness, initiation the eco-development long-term projects, the establishing of village-owned tree plantations, law enforcement and designating as eco-tourism site.

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