Leaflet No. 32/2019

The Republic of the Union of Myanmar

Ministry of Natural Resources and Environmental Conservation

Forest Department

Patterns of Deforestation and Forest Degradation in Myanmar; Policy Interventions for Improving Forest Conservation and Management

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December, 2019

Content

မြန်မာနိုင်ငံသစ်တော ပြုန်းတီးခြင်း၊ သစ်တောအတန်းအစားကျဆင်းခြင်းပုံစံနှင့် သစ်တောထိန်းသိမ်းခြင်း၊စီမံအုပ်ချုပ်ခြင်းလုပ်ငန်းများ ဖွံ့ဖြိုးတိုးတက်စေရေးအတွက် အကြံပြုတင်ပြခြင်း

ဒေါ်နိုင်ထွန်း၊ ဦးစီးအရာရှိ
သစ်တောဦးစီးဌာန၊ ရှမ်းပြည်နယ်

စာတမ်းအကျဉ်း

မြန်မာနိုင်ငံသည် အရှေ့တောင်အာရှဒေသ အဓိကကုန်းမြေပေါ်တွင် သစ်တောဖုံးလွှမ်းမှု အများဆုံးဖြစ်သည့် နိုင်ငံများထဲမှ တစ်နိုင်ငံဖြစ်ပြီး ကမ္ဘာလုံးဆိုင်ရာအရေးပါသည့် ဇီဝမျိုးစုံ မျိုးကွဲများတည်ရှိရာ ဒေသတစ်ခုဖြစ်ပါသည်။ သို့သော် သစ်တောဖုံးလွှမ်းမှုသည် ၁၉၉၀ ခုနှစ်တွင် ၅၈ ရာခိုင်နှုန်း ရှိခဲ့ရာမှ ၂၀၁၅ ခုနှစ်တွင် ၄၄ ရာခိုင်နှုန်းထိ လျော့နဲသွားခဲ့ပြီး ၂၀၁၀ ခုနှစ်နှင့် ၂၀၁၅ ခုနှစ် အတွင်း ကမ္ဘာပေါ်တွင် သစ်တောပျက်စီးမှုနှုန်း တတိယအများဆုံးနိုင်ငံဖြစ်ခဲ့ပါသည်။ နှစ်ပေါင်းများစွာ စစ်အာဏာရှင် အုပ်ချုပ်မှုစနစ်၏ အကျိုးဆက်အဖြစ် လက်ရှိဒီမိုကရေစီအစိုးရ လက်ထက်တွင် သစ်တောပြုန်းတီးမှုနှင့် ပတ်ဝန်းကျင်ဆိုင်ရာ ပြဿနာမျိုးစုံ ရင်ဆိုင်ဖြေရှင်း လျှက်ရှိပါသည်။ ဤသုတေသနစာတမ်း၏ ရည်ရွယ်ချက်မှာ ၂၀၀၅ ခုနှစ်မှစ၍ မြန်မာနိုင်ငံ၏ သစ်တောပြုန်းတီးမှု ပုံစံနှင့် ပြုန်းတီးမှုနှုန်းထားများအား နားလည်သိရှိပြီး မြန်မာ့သစ်တော စီမံအုပ်ချုပ်လုပ်ကိုင်မှု ဖွံ့ဖြိုးတိုးတက်စေရန် သင့်လျော်သော မူဝါဒများချမှတ်ခြင်း အတွက် အထောက်အကူ ပြုနိုင်ရန် ရည်ရွယ်ပါသည်။ ၂၀၀၅၊ ၂၀၁၀ နှင့် ၂၀၁၅ ခုနှစ်တို့အတွက် ဂြိုလ်တု ဓါတ်ပုံများမှ ရရှိသောမြေ အသုံးချမှုဆိုင်ရာမြေပုံများအား မြန်မာနိုင်ငံ၊ သစ်တောဦးစီးဌာနမှ ရယူသုံးစွဲခဲ့ပြီး သုတေသန စာတမ်းများ၊ အစီရင်ခံစာများကို လေ့လာဖတ်ရှု ပြုစုခဲ့ပါသည်။ သစ်တော ဖုံးလွှမ်းမှု ပြောင်းလဲခြင်း၊ လျော့နည်းခြင်းများ ဆန်းစစ်ခြင်းအား ArcGIS (10.6) software အသုံးပြုဆောင်ရွက်ခဲ့ပါသည်။ သုတေသနရလာဒ်များအရ ၂၀၀၅ ခုနှစ်နှင့် ၂၀၁၀ ခုနှစ် အတွင်း သစ်တောဖုံးလွှမ်းမှု ၂.၅၈ ရာခိုင် နှုန်းနှင့် ၂၀၁၀ နှင့် ၂၀၁၅ ခုနှစ်အတွင်း ၀.၉၇ ရာခိုင်နှုန်း လျော့နည်းသွားကြောင်း တွေ့ရှိခဲ့ပါသည်။ သုတေသနဆန်းစစ်ချက်များအရ သစ်တောအပြောင် ရှင်းလင်း၍ ပြုန်းတီးခြင်းထက် သစ်တောရွက်အုပ် ဖုံးလွှမ်းမှုလျော့ကျပြီး သစ်တောအတန်းအစား ကျဆင်းခြင်းမှတဆင့် အခြားမြေ အသုံးချမှုများ ဝင်လာပြီး ပျက်စီးခြင်းဖြစ်ကြောင်း တွေ့ရှိရပါသည်။ သုတေသနစာတမ်းမှ အကြံပြုချက်များမှာ အဓိက ဇီဝမျိုးစုံမျိုးကွဲများတည်ရှိပြီး ကာကွယ် ထိန်းသိမ်းခြင်းလုပ်ငန်းများ ဆောင်ရွက်နိုင်ခြင်း မရှိသေးသောနေရာများအတွက် သဘာဝ ထိန်းသိမ်းရေး နယ်မြေများ တိုးချဲ့ဖွဲ့စည်းခြင်းအား ဦးစားပေး ဆောင်ရွက်သင့်ပါကြောင်း၊

မြန်မာ့သစ်တော ထိန်းသိမ်းကာကွယ်ခြင်းနှင့် စီမံအုပ်ချုပ်ခြင်းတို့အတွက် ဒေသခံပြည်သူလူထု ပူးပေါင်းပါဝင်မှု အားကောင်းလာစေရန် အလေးထားဆောင်ရွက် သင့်ပါကြောင်း၊ မြန်မာ့သစ်တော စီမံအုပ်ချုပ်မှုတွင် ပြည်ထောင်စုအစိုးရမှ တိုင်းဒေသကြီး/ပြည်နယ် အစိုးရများသို့ လုပ်ပိုင်ခွင့် အာဏာ များခွဲဝေ တိုးမြှင့် ပေးသင့်ပါကြောင်း၊ သစ်ကုန်သွယ်မှုကဏ္ဍတွင် အဂတိလိုက်စားမှု စနစ်မှ ရုန်းထွက် နိုင်ရန်အတွက် ဒေသခံအသေးစားနှင့်အလတ်စား ရောင်းဝယ်ရေးလုပ်ငန်းများ ဖွံ့ဖြိုး တိုးတက်လာစေ ရန်အားပေးကူညီဆောင်ရွက်သင့်ပါကြောင်းနှင့် မြန်မာ့သစ်တောစောင့်ကြည့် အကဲဖြတ်ခြင်းတွင်အဆင့် မြင့် Remote Sensing and GIS နည်းပညာများ အသုံးပြု၍ ဖွံ့ဖြိုးတိုးတက်လာစေရန် တွန်းအားပေး ဆောင်ရွက်သင့်ပါကြောင်း အကြံပြု တင်ပြအပ်ပါသည်။

Patterns of Deforestation and Forest Degradation in Myanmar; Policy Interventions for Improving Forest Conservation and Management

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Abstract

Myanmar is one of the most forested countries of mainland Southeast Asia and is a globally important biodiversity hotspot. However, forest cover has decline from 58% in 1990 to 44% in 2015, and had the third highest rate of deforestation between 2010 and 2015. After years of military dictatorship, a newly democratic government was formed in 2015 and is facing many environmental issues. The aim of this paper was to understand the patterns and rates of deforestation and forest degradation in Myanmar since 2005, and to identify possible policy interventions for improving Myanmar's forest management. Remote sensing derived land cover maps of 2005, 2010 and 2015 were accessed from the Forest Department, Myanmar. Post–classification change detection analysis and cross tabulation were completed using spatial analyst and map algebra tools in ArcGIS (10.6) software. The results showed the overall annual rate of forest cover loss was 2.58 % between 2005 and 2010, and 0.97 % between 2010 and 2015. The change detection analysis showed that deforestation in Myanmar occurred mainly through the degradation of forest canopy rather than forest clearing. We propose that strengthening the protected area system in Myanmar, where the Key Biodiversity Areas (KBAs) are not currently protected, should be a priority. We also emphasise the importance of community participation in forest conservation and management. There needs to be a reduction in centralisation of forestry management by sharing responsibilities with local governments and the movement away from corruption in the wood trading industry through the formation of local–based small and medium enterprises. We also recommend the development of a forest monitoring program using advanced remote sensing and GIS technologies.

Keywords: Deforestation, Forest Degradation, Land use, Landcover Change, Myanmar

Patterns of deforestation and forest degradation in Myanmar; policy interventions for improving forest conservation and management

1. Introduction

Myanmar is located at the junction of the Himalayan, Indochinese, and Malayan Peninsular eco-regions (MOECAF, 2014). It has high spatial variations in rainfall and temperature with over 40% of mountainous topography, diverse river systems and forest ecosystems. Forest types include alpine in the northern mountainous region, dry and deciduous forests in the central dry ecosystems, and rainforests and mangroves on the southern floodplains (MOECAF, 2014). These diverse ecosystems are home to a wide range of habitats and wildlife, including many endemic species. The IUCN claim "the country is home to 10% of the world's freshwater turtles and tortoises on just over 1% of the world's land area, and at least 250 mammal species and more than 1,000 bird species. Its forests represent some of the most extensive and intact in Southeast Asia" (IUCN, 2018). However, many of Myanmar's diverse range of ecosystems have been degraded after more than 50 years of political and economic hardship. Restoration of many ecosystems is urgently required.

Myanmar has a total land area of 676,600 km^2 and an estimated population of 53.37 million in 2017 (World Bank, 2019). Its forests are a globally important and highly threatened biodiversity hotspot (Hughes, 2017). The Forest Resource Assessment (2015) found forest cover declined from 58% in 1990 to 44% in 2015 and virtually all of Myanmar's more accessible forests are shrinking rapidly in both extent and quality. According to the FAO (2015), Myanmar had the third highest global rate of deforestation, losing 546,000 ha annually after Brazil and Indonesia between 2010 and 2015. The reduction in forest quality (structural and compositional integrity) is even more serious from a biodiversity and livelihoods perspective. In 1989, contracts were made with Thai logging companies for logging border areas with Thailand and likewise, in Kachin State, where Chinese companies gained informal logging rights. In both cases, logging activities have lacked effective monitoring (FD, 2015). The Myanmar Forest Department, which officially governs almost all of the country's forest area, has had little effective authority over these operations because of political difficulties and has rarely been in a position to ensure that the logging was sustainable. After years of military dictatorship, a newly elected government was formed in 2015, and is facing many environmental issues and natural disasters such as severe storms, drought, and flooding. Studies have reported that many of these issues are related to the deforestation and forest degradation due to unsustainable management and overexploitation of Myanmar's natural resources (Lim et al. 2017; Pasha et al., 2019; Prescott et al., 2017 and Zhang et al. 2018). With the recent political change, central government control has been reduced by a power sharing arrangement between regional and state governments. These agencies require more rigorous scientific information to ensure sustainable management and decision making in their specific state or region, and for the country as a whole.

Determining the patterns and rates of deforestation and forest degradation in Myanmar is an essential step for conserving Myanmar's forest. Land cover mapping through the use of remote sensing (RS) and geographical information systems (GIS) has been developed over the past decades, and applied to assess Myanmar's forest cover (for example; FREL, 2018; Htun, Mizoue, & Yoshida, 2013; Leimgruber et al., 2005; Liu et al., 2016; Mon, Mizoue, Htun, Kajisa, & Yoshida, 2011; Shimizu et al., 2017; Tejas et al., 2017 and Wang & Myint, 2016).

In this paper, we investigate how the extent of Myanmar's forests has changed since 2005. We quantify the patterns and rates of deforestation and forest degradation for the major ecosystems for the whole of Myanmar and for the administrative states using 2005, 2010 and 2015 remote sensing derived land cover maps and GIS-based change detection analysis. We then provide insight into possible policy interventions for improving Myanmar's forest management.

2. Material and Methods

2.1 Data Sets and Limitations

Land cover maps of 2005, 2010 and 2015 were accessed from the Forest Department, under the Ministry of Natural Resources and Environmental Conservation (MONREC), Myanmar. Data acquisition, image processing, and land cover classifications were conducted by staff within the Remote Sensing and Geographic Information System section, at the Headquarters Office of the Forest Department. In 2015, MONREC and FAO jointly implemented a capacity building program to help strengthen Myanmar's national forest monitoring and land-use assessment. The project trained 12 young staff at the RS/GIS unit to produce the 2015 national forest cover map following the Intergovernmental Panel on Climate Change (IPCC) guidelines (Aung, 2016).

A supervised maximum likelihood classification method was used to classify pixel-based land cover classes from 30 m Landsat imagery for 2005 and 2015, and 23.5 m LISS-3 imagery for 2010 (FREL, 2018). For 2005 land cover products, imagery from 2006 Landsat 7 ETM was used for the majority of the country, with 2007 and 2008 imagery from the same sensor incorporated for gap regions, with the exception of Shan State, which utilised 2005 Landsat 5 TM imagery (FAO, 2015). The 2010 products were generated from a combination of 2010 LISS-3 and 2010 Landsat 7 ETM imagery to cover the entirety of the country. The 2015 series of land cover products relied on Landsat 8 OLI imagery acquired between October 2014 and March 2015. Geometric correction was performed using Geometica software and mosaicked for all states and regions, and radiometric and atmospheric corrections were conducted to improve the interpretability of imagery. The 6, 5, 4 (SWIR, NIR, R) Landsat band combination was used to classify land cover classes due to its high spectral variation allowing for the creation of fifty Regions of Interest for each land cover class incorporating shape, type, colour, and texture with Google Earth as a ground truth tool. Finally, a supervised maximum likelihood classification was applied to produce a thematic land cover map (Aung, 2016).

The raster files have certain limitations (RREL, 2018), For example, not all satellite imagery was collected from the same referenced year but from the consecutive years if cloud free images were not available (e.g. for 2005 map, images from 2005, 2006 and 2007 were used). There was also no standard operating procedure for mapping at different time points and upgrading of map quality is still required. Leimgruber et al., (2005) and Tejas et al., (2017) suggest the post-monsoon months from December to February as the most useful for forest cover mapping in Myanmar due to the lower cloud cover and lush vegetation cover. Acquiring the same anniversary images can minimise the influence of tree phenological differences and sun-angle, which can have adverse impacts and change detection analysis (Jensen, 2013; Lu, Mausel, Brondízio, & Moran, 2004; Pontius, Shusas, & McEachern, 2004; Ward, Phinn, & Murray, 2000). Hence, it could also have a negative impact on image classification if there is a wide range of acquired satellite images.
The lack of formal accuracy assessment of classified maps, with the exception of 2015, is the main limitation of the study (Aung, 2016). Accuracy assessments for the 2005 and 2010 maps have not been performed, although expert knowledge and the field experience of the analysts contributed to the validation of the classification of land cover classes. Google Earth was the primary source for accuracy checks, and the lack of ground truthing through field surveys due to inaccessibility as well as poor internet access at the time of the classification process is a limitation. Townshend et al., (2012) stated that reliable reference datasets or fine resolution images are essential for estimating the accuracy results of classified maps. The final accuracy of the land cover products used for analysis is relatively high when compared to other studies (e.g., Feng, Lu, Moran, & Falcão de, 2017; Im, Rhee, Jensen, & Hodgson, 2007 and Parihar, Sarkar, Dutta, Sharma, & Dutta, 2012).

In spite of these limitations, the quality of maps was considered adequate for the application of change detection analysis. The raster land cover data for each year have seven land cover classes and descriptions of classes (Table 1). The percentage of annual forest loss (r) was calculated by applying formula according to Puyravaud (2003). The formula is derived from Compound Interest Law and the mean annual rate of change, and is more intuitive than the formula used by the FAO ($q = (A2/A1)^{(1-t2/t1)}-1$).

$$r = \frac{1}{t2-t1} \ln \frac{A2}{A1},$$

Where 'r' represents the annual rate of forest change, A1 and A2 are the area of each forest cover class at *t1* and later time, *t2* respectively. Following (Mon et al., 2011), the canopy cover was applied as the indicator of deforestation (forest to other landcovers) and forest degradation (closed forest to open forest cover).

Table 1. Landcover classes and descriptions (FAO, 2015)

Landcover class	Descriptions
Closed Forest	Under forestry or no land use, spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of more than 40 percent, or trees able to reach these thresholds in situ.
Open Forest	Under forestry or no land use, spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover between 10 and 40 percent, or trees able to reach these thresholds in situ.
Mangrove	Area covered by Mangrove tree species as interpreted from satellite imagery and aerial photographs.
Other wooded land	Areas mostly covered by grassland and stunted trees, shrub forests, lower that 10% crown density.
Other	All land that is not classified as the above classes (e.g. agricultural land, settlement areas, rock, bareland, sandbanks).
Water	Inland water bodies, lakes, reservoirs, large streams and rivers.
Snow	Snow cover in mountainous areas.

2.2 Post classification Change Detection Analysis

Change detection analysis and cross tabulation were completed using spatial analyst and map algebra tools in ArcMap (10.6 version). The GIS workflow of change detection analysis is illustrated in Appendix 1. Post-classification change detection requires rectified and classified thematic maps beforehand to implement comparison based on pixel by pixel (Hussain, Chen, Cheng, Wei, & Stanley, 2013). Im et al., (2007) states that post-classification comparison has been one of the more widely used change detection techniques to extract detailed "from–to" change information. Its ultimate advantage is that it provides a complete matrix of change information (Lu et al., 2004). It also reduces the impacts of atmospheric, sensor, and environmental differences between multi-temporal images. The general cross-tabulation matrix that produces gains, losses and persistence of the two compared maps are shown in Appendix 2 and is according to Pontius et al., (2004). Forest cover maps were overlaid with state and regional boundaries to analyse the forest cover changes in each state and region. The state and regional boundaries layer was downloaded from the Myanmar Information Management Unit (MIMU), (https://bit.ly/2YnYJ8C).

3. Results

The results from the change detection analysis are described in the following sections; (1) major changes of land cover and deforestation, (2) 'from-to' change information of land cover classes, and (3) land cover changes across states and regions.

3.1 Major Changes of Land Cover and Deforestation

During the periods 2005-2010 and 2010-2015, significant land cover changes occurred. For the whole of Myanmar, forest cover was lost at an annual rate of 2.58% between 2005 and 2010, and 0.97% between 2010 and 2015. The area of closed forest cover was reduced from 19.6 Mha in 2005 to 14.9 Mha in 2010 and 12.5 Mha in 2015. Correspondingly, open forest cover increased from 15.9 Mha in 2005 to 16.3 million hectares in 2010 and 17.2 Mha in 2015. Over the study period, closed forest cover was significantly reduced while open forest and other wooded land cover classes notably increased (Figure 1, Appendix 3). As Closed forest cover was reduced by 5.44% annually during the first study period, which was higher than for the second period at 3.54% annually. Mangroves were also reduced at 0.19% for 2005-2010 and 1.58% for 2010-2015. Land cover and change detection maps are shown in Figures 2, 3 and 4. Other wooded land cover increased from approximately 12.8 million hectares in 2005 to 14.0 and 18.9 million hectares in 2010 and 2015 with an annual increase at 1.90% and 5.98% for first and second period respectively. Others landcover class increased at 2.98% for 2005-2010 and reduced at 2.93% for 2010-2015. The similar changes to water landcover class were found, and snow cover was reduced during both study periods.

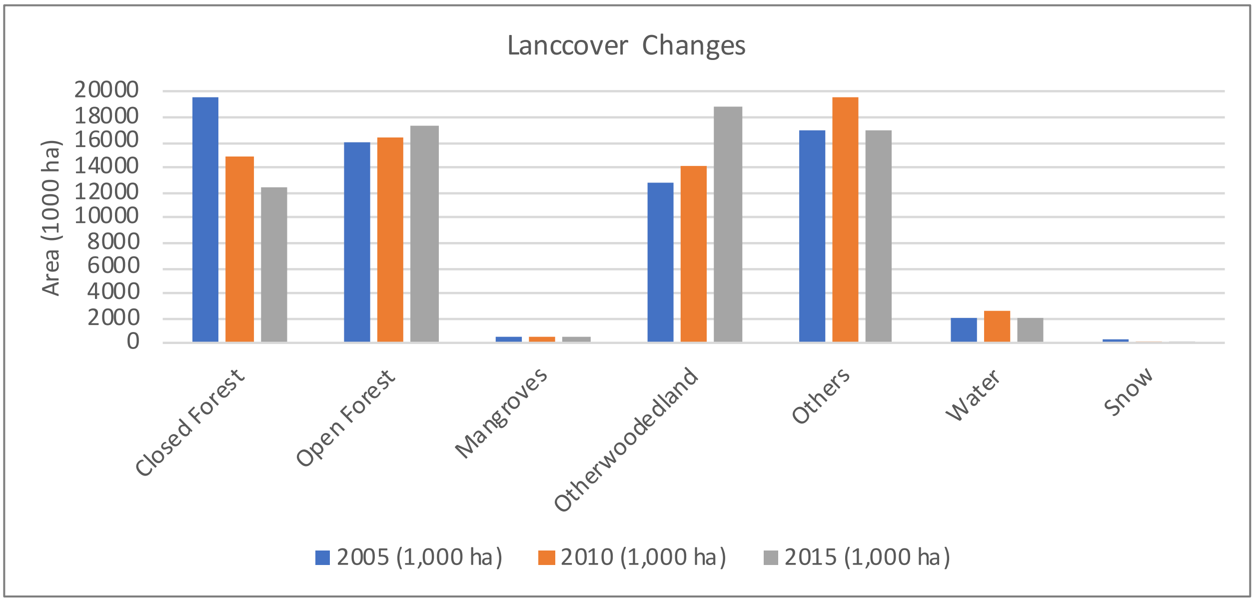

Figure 1. Graphical summary of landcover changes between 2005, 2010 and 2015

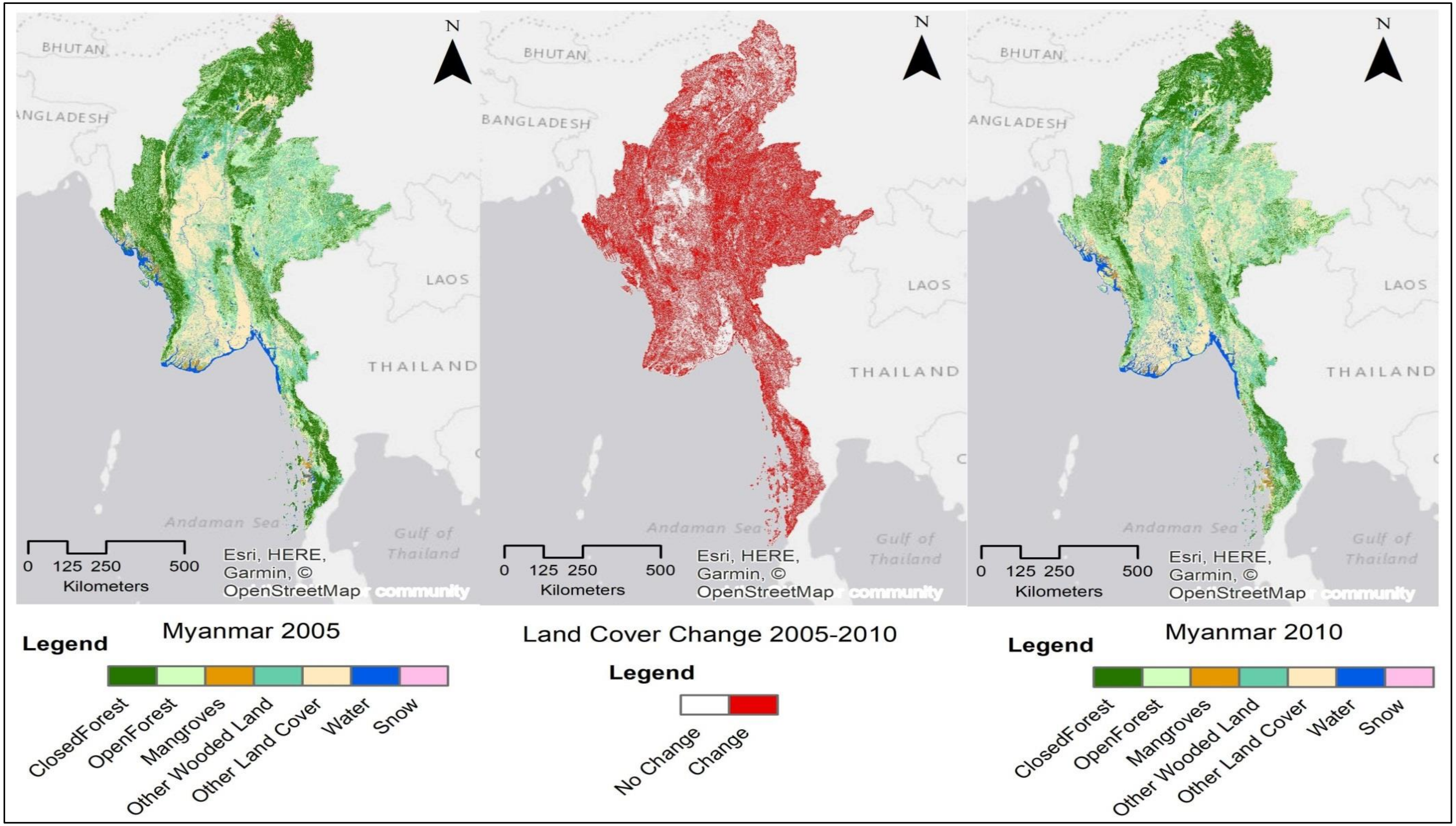

Figure 2. Land cover maps of 2005 and 2010, and the binary change detection map. The red colour in the center map represents change areas between 2005 and 2010.

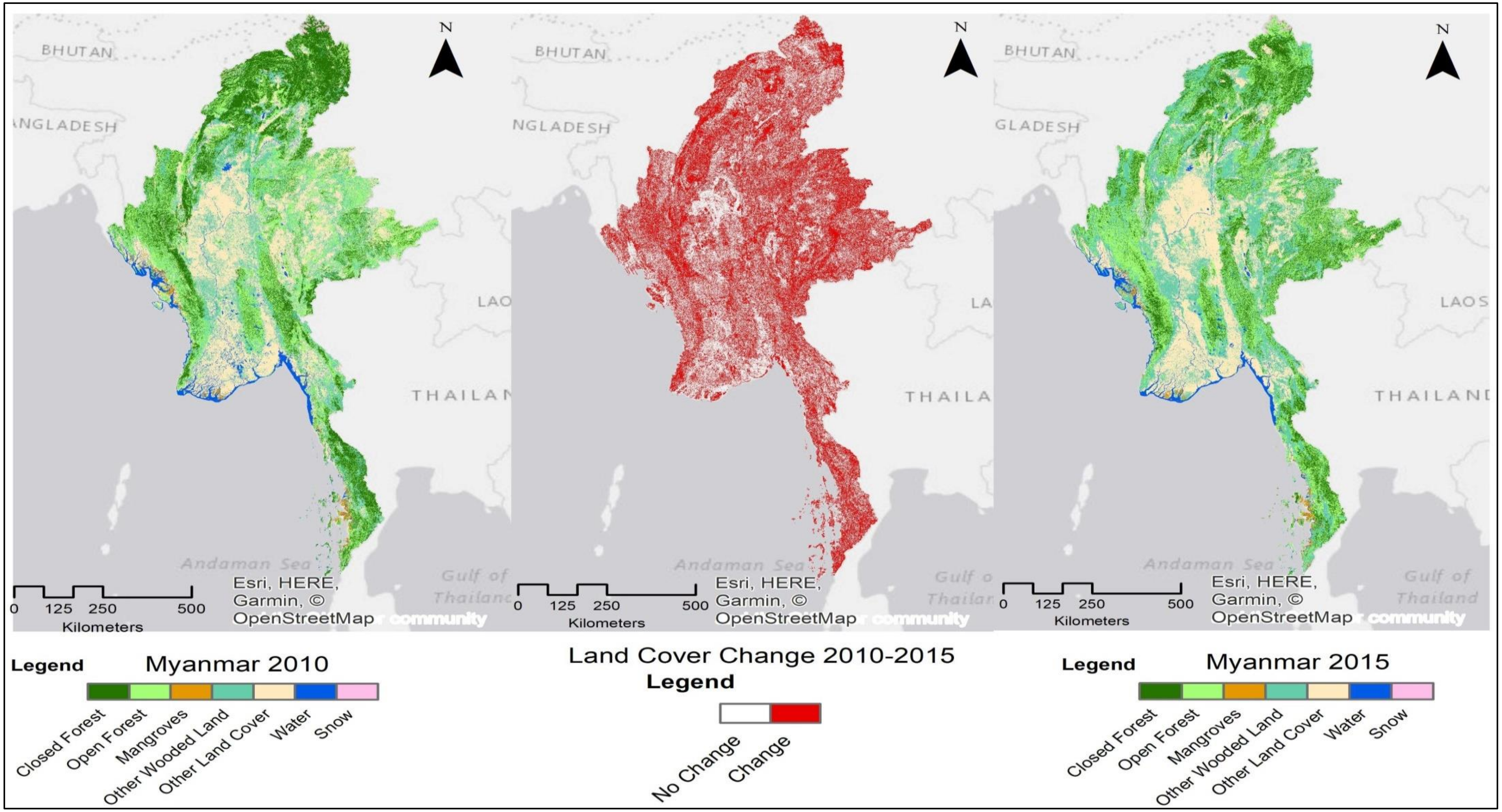

Figure 3. Land cover maps of 2010 and 2015, and the binary change detection map. The red colour in the centre map represents change areas between 2010 and 2015

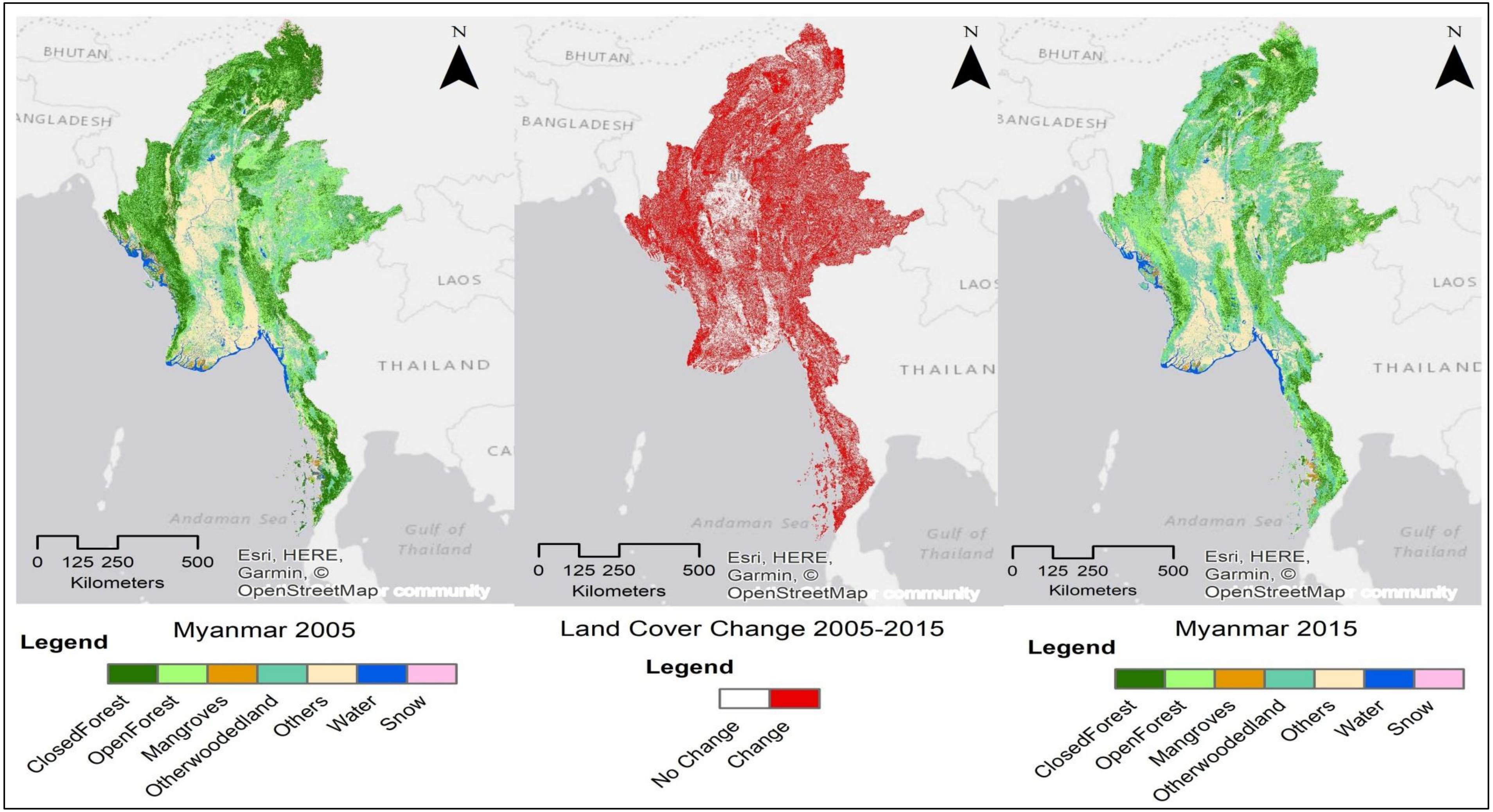

Figure 4. Land cover maps of 2005 and 2015, and the binary change detection map. The colours in the center map represents change areas between 2005 and 2015

3.2 'From-to' Change Information of Land Cover Classes

One of the objectives of this study was to understand how Myanmar's forest cover has changed over time during the study periods. The strongest changes occurred among the closed forest, open forest, and other woodland classes. Between 2005 and 2010, approximately 238,000 hectares of closed forest changed to open forest and 105,000 hectares of open forest were converted to woodland, while 84,000 hectares of the closed forest changed to woodland. Therefore, closed forests are more likely to change to open forest rather than other woodland. Likewise, a similar pattern of change occurred between 2010 and 2015 where 372,000 hectares of closed forest were transformed to open forest. In comparison, 50,000 hectares were converted to other woodland, which is about 7-times lower than the change rate of closed to open forest. Figures 5 compares and illustrates the changes of closed forest and open forest to other land cover classes between two study periods.

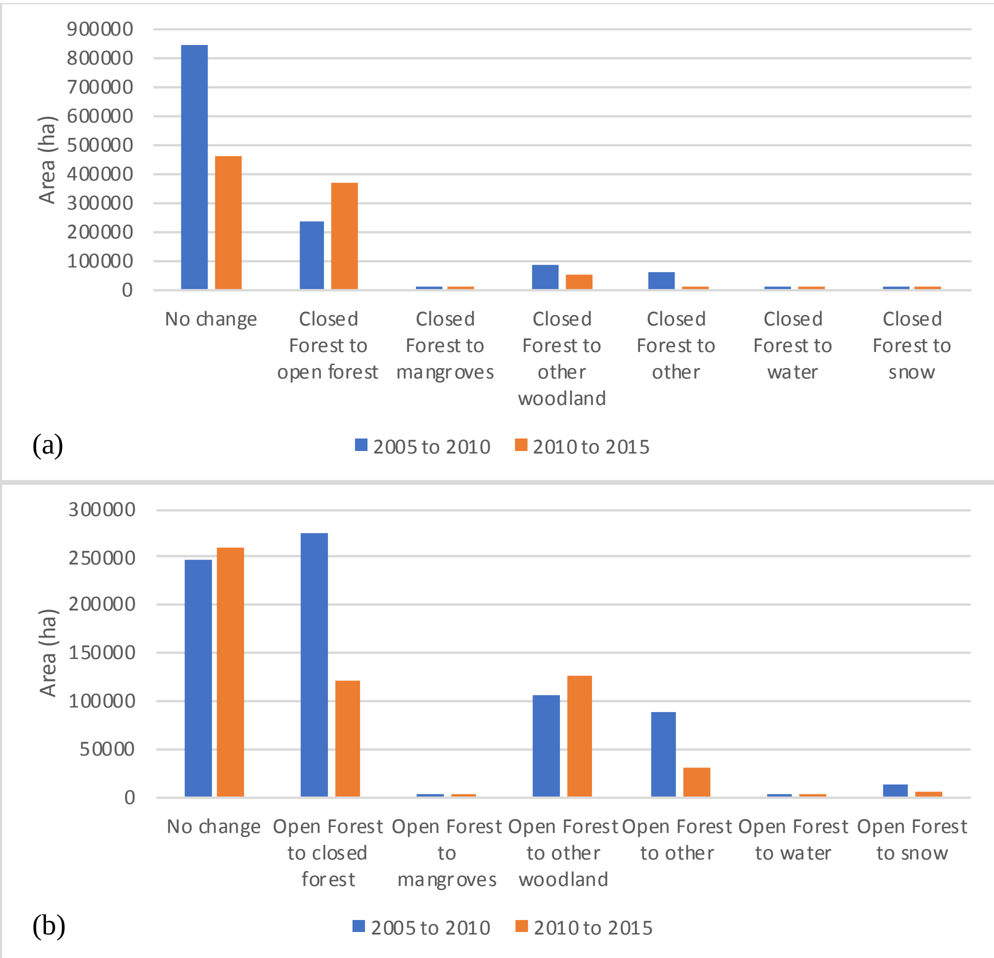

Figure 5. Changes from (a) closed forest and (b) open forest to other land cover classes during study periods

3.3 Land Cover Changes by States and Regions

Natural forest areas are predominantly found in Kachin, Shan, Sagaing, Tanintharyi, and Chin followed by Rakhine, Kayin, and Bago. The most significant changes occurred in Kachin state, followed by Sagaing, Shan, and Tanintharyi respectively whereas deforestation and forest degradation occurred across the country. Figure 6 shows the closed and open forest cover changes across the states and regions during the study periods.

The change-detection forest cover maps show that forest hotspots were located in the states of Kachin, Shan, Sagaing, and Tanintharyi. Most of these hotspots occurred on the upland areas, Kachin and Shan bordering with China, and in Tanintharyi region which borders with Thailand. The change detection analysis reveals that Kachin followed by Shan, Sagaing and Tanintharyi experienced the greatest deforestation and forest degradation during the study periods. Moreover, open forest cover increased in Chin state, and Sagaing and Tanintharyi regions. High-density population regions such as Yangon, had few forest areas and the central areas such as Mandalay and Magway are highly populated and less forested with dry forests, open forests and savannas dominating.

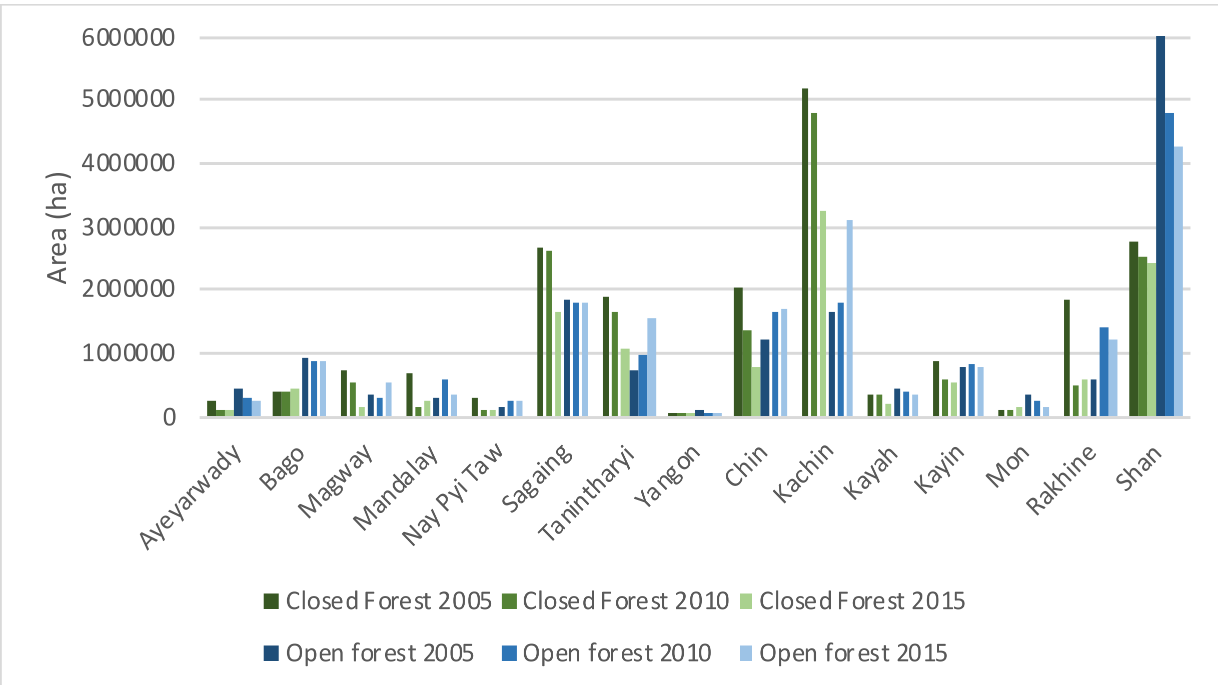

Figure 6. Closed and open forest cover changes by state and region

4. Discussion

Extensive deforestation and forest degradation occurred in Myanmar during both 2005-2010 and 2010-2015. The annual rate of deforestation decreased from 2.58% for the first period to 0.97%

for the second period. The reduced rate coincides with the political transition period when the elected government started in 2010 and the military-ruled government ended under the 2008 Constitution. Therefore, the patterns and rates of forest cover loss in Myanmar are potentially influenced by the constitutional and political change. Forest losses occurred mainly through forest degradation rather than direct deforestation. The reason for this may be due to the nature of the Myanmar Selection System (MSS) of timber harvesting in place since 1856, followed by illegal logging, charcoal, and fuelwood collection. These degraded forests are likely to be replaced by commercial plantations or subsistence agriculture (Treue et al., 2016).

4.1 Drivers of Deforestation and Forest Degradation

The drivers of deforestation and forest degradation are complex given the local context (Lambin, Geist, & Lepers, 2003). There are a number of proximate and underlying causes of forest loss and degradation in Myanmar. Depending on the local context, the major drivers of deforestation and forest degradation in Myanmar will be discussed as follows: (1) agricultural expansion, (2) legal and illegal logging, (3) fuelwood and charcoal consumption, (4) road construction, and (5) mining and dam construction.

4.1.1 Agricultural expansion

Agricultural expansion is a key driver of global deforestation (Jonathan et al., 2011 and Zhang, et al., 2018). In recent decades, agriculture is increasing in the tropics, where 80% of new croplands have replaced natural forests (Zhang, et al., 2018). New land demand for agriculture is likely to be focused on tropical developing nations where there are large forested areas suitable for agriculture (Jonathan et al., 2011). Myanmar, which has recently been opened to the world communities after a long military dictatorship (1962-2011), is expected to encounter rapid agriculture-driven deforestation (Jonathan et al., 2011). With the election of the democratic government in the 2015 general election, the agricultural sector is likely to develop due to improved access to international markets and private sector investment. Consequently, agricultural expansion at the expense of forests and biodiversity is expected through the development of technology and infrastructure (Webb et al., 2014).

Lim et al., (2017) who studied proximate causes and underlying drivers of deforestation and forest degradation in Myanmar between 1995 and 2016, identified agricultural expansion as a direct cause and major driver of forest loss and degradation in Myanmar. Likewise, other studies Treue, Springate-Baginsk, & Htun, (2016) and UN-REDD, (2017) point out that commercial agriculture such as palm oil and rubber plantations have contributed more to Myanmar's deforestation than subsistence agriculture. Moreover, Donald et al., (2015) stated that agricultural concessions granted in 2010 and 2012 in the Tanintharyi region, which borders with Thailand, were approved in densely forested areas of the proposed Lenya national park. Those land concessions were mainly accessed by companies that had a strong relationship with the military. Prior to agricultural rights, the companies were able to extract the timber value from the land (Woods, 2015). Although they cleared the land of timber but then did not turn the land into agriculture as per the concession. Only less than 25% of the 2 million ha granted between 2012 - 2013 were converted to agriculture (Woods, 2015). However, the unused or unsuitable commercial concessions have been revoked by the MONREC (Donald et al., 2015). Daniel & Daniel, (2016) also found that mangrove forest loss was often associated with the expansion of aquaculture, especially shrimp farms, during the 2000 - 2012 period in Myanmar. Other studies of the Ayeyarwady delta region of Myanmar also confirmed that agricultural expansion attributed to mangrove losses between 2000 and 2013 (Webb et al., 2014).

Land areas with high potential yield for agriculture are mainly located in the mountainous states and regions that have experienced civil wars (Zhang, Prescott, Tay, Dickens, Webb, Htun, Tizard, Rao, et al., 2018). Insecure land tenure has further hindered agricultural expansion in those regions over the past decades. However, the allocations of commercial agricultural concessions following cease-fire agreements and the peace process between the ethnic armed groups and military have also contributed to deforestation. For example, the allocation of cassava agribusiness concessions to a "crony" company in a previously protected area of Hukaung Valley (Grundy-Warr & Wong Siew Yin, 2002 and Woods, 2011, 2015). Also, Lim et al., (2017) state that large-scale deforestation occurred after ceasefire agreements in these uplands. Therefore, Zhang et al., (2018) expected greater deforestation following the peace process due to economic development in the border areas and suggested that conservation could be crucial to achieve a sustainable forest transitions in those regions.

4.1.2 Legal and illegal logging

Although Myanmar has been historically practicing science-based forest management with the Myanmar Selection System (MSS), studies have shown that unsustainable timber extraction has contributed to Myanmar's deforestation and forest degradation. Selective logging practice is commonly used in most tropical forests worldwide and there have been increasing concerns about the sustainability of wood exploitation (Hla Maung, Kanzaki, Fukushima, & Yazar, 2007; Sist & Ferreira, 2007 and Sist, Mazzei, Blanc, & Rutishauser, 2014). An analysis of Myanmar's forest cover loss by Lim et al., (2017) revealed that logging was one of the main causes of forest loss or degradation from 1995 to 2016. In Myanmar, the Forest Department and the Myanmar Timber Enterprise are the two government organisations responsible for commercial logging operations. The Forest Department plays a forest conservation role, while the Myanmar Timber Enterprise is responsible for wood extraction. However, during recent decades, commercial logging was sub-contracted to approximately 100 companies in the pursuit of foreign income through the export of timber mainly to China (Woods, 2011). Although the annual allowable cut and 30 years cutting frequency of production forests are the foundation rules of the Myanmar Selection System, the annual cutting on the ground were more likely to exceed the allowable cut (Woods, 2015). Under the Myanmar Selection System, valuable trees such as teak (*Tectona grandis*) and other hardwoods are selectively logged within the production forests leading to forest degradation. In addition, illegal logging has followed legal logging and further contributed to forest degradation in Myanmar (Win, Mizoue, Ota, Wang, et al., 2018). Illegal logging has occurred for both timber extraction and charcoal (Khai, Mizoue, Kajisa, Ota, & Yoshida, 2016). A study of the Bago mountain range, which is well-known as the 'Home of Teak' in Myanmar found that about 59.8% of the disturbed areas were caused by logging impacts and was followed by water infrastructure development due to dam construction (Shimizu et al., 2017). Similarly, other studies (e.g., Khai et al., 2016; Mon et al., 2011 and Rosy Ne, Suzuki, & Takeda, 2009) reveal that both legal and illegal logging activities had a substantial impact on deforestation and forest degradation in Myanmar. The report by the UN states that government, research, and NGO's concur that the legal but unmonitored harvesting of teak and other valuable hardwoods for decades and the supply of the illegal timber market has contributed to Myanmar's deforestation and forest degradation (UN-REDD, 2017). Consequently, timber production in Myanmar has gradually decreased in both quality and quantity while natural forest areas are rapidly depleted (Springate-Baginski, Thein, Neil, Thu, & Doherty, 2014). While 28% of tropical forests worldwide are utilised for wood production (Laurance, Goosem, & Laurance, 2009), 35% of Myanmar's natural forests are used for commercial wood production and suffer from forest degradation rather than deforestation (Mon, Kajisa, Mizoue, & Yoshida, 2010 and Mon et al., 2011). Treue et al., (2016) also assert that there has been a rapid decline of growing stock over the past two decades, highlighting a reduction in the AAC of Myanmar's forests. This is the result of focusing heavily on timber exports to earn foreign revenue by the previous government. Observations in Kachin and Sagaing indicate that teak-producing forests are encountering severe forest degradation and are being exploited for teak and other hardwood species regardless of the prescribed 30 years rotation (Treue et al., 2016). Based on remote sensing and visual observations, it was inferred that over-logged areas were used for charcoal and fuelwood productions, which seemed to be the final stage before permanent conversion to agriculture or plantations (Treue et al., 2016).

Moreover, EIA (2015) revealed that the amount of illegal timber traded across Myanmar's borders is significant and has been occurring for more than two decades. High demand for wood from China, Thailand, and Vietnam continues to exert pressure on Myanmar's forests, due to logging bans on their own natural forests. There are 39 main tracks across Myanmar's borders along which the illegal timber trade is conducted, with 25 tracks leading to China, six to Bangladesh, two to India, and six to Thailand (ITTO, 2016). According to a comparison of official government data and global market records for Myanmar's log exports during 2001 and 2013 (EIA, 2014), there were 10.2 million m^3 of logs that were not authorised for harvest, revealing an illegal logging rate of 47%.

4.1.3 Fuelwood and charcoal consumption

About 2 billion people in the developing world are still mainly depending on fuelwood and charcoal for cooking and heating in both rural and urban areas (FAO, 2010). According to the 2014 Myanmar Population and Housing Census (DOP, 2015), approximately 69% and 12% of households in Myanmar are using firewood and charcoal respectively for cooking. Thus, 81% of households in Myanmar depend on wood derived energy sources for cooking, while only 16% use electricity for cooking. Moreover, about 52% of urban households also rely on either firewood or charcoal for cooking. Fuelwood and charcoal use in Myanmar have contributed to deforestation (Leimgruber et al., 2005; Mon et al., 2011 and Webb et al., 2014). In a study of charcoal production and environmental impacts in tropics worldwide, Chidumayo & Gumbo, (2012) stated that approximately 7% of total forest cover loss in tropical countries was attributed to charcoal production. There has been rising concerns of the environmental impact of charcoal consumption rather than firewood consumption due to the nature of charcoal production that uses live trunks and big branches (Bensch & Peters, 2013 and Win, Mizoue, Ota, Kajisa, et al., 2018), while dead wood and small branches are used for firewood (Top et al., 2006). A study of the differences in consumption rates and patterns of firewood and charcoal use in Myanmar reported that the production of fuelwood is unlikely to be a direct cause of forest loss. Nevertheless, the current and increasing demand for charcoal in Myanmar is likely to lead to a higher number of tree cuts that may result in further forest degradation. According to the UN-REDD Report (2017), an estimated annual volume of fuelwood collected during 2000-2013 in Myanmar was approximately 70 million m^3, mainly extracted from natural forest. It was also much higher than annual timber extraction (based on official data) of 4 million m^3 and therefore, it is one of the major causes of forest degradation and deforestation in Myanmar. Myanmar is also one of the world's largest fuelwood and charcoal exporting nations accounting for an annual value of US$ 30.5 million (Trends, 2014). Charcoal exports through the illegal market along the border areas of China boomed between 2006 and 2008 and are likely to continue to increase due to increasing demand from the Yunam Province, China. Therefore, fuelwood collection and charcoal production could be considered a major cause of deforestation and forest degradation in Myanmar.

4.1.4 Road construction

Myanmar's forest loss over the past decades has also been attributable to the construction of new highways and main roads (Liu et al., 2016). Liu et al., (2016) discussed the status of the Asian Highway system in Myanmar, made up of four main routes linking Myanmar with China, India, and Thailand. These routes pass through Myanmar's remaining pristine forests. Forest cover loss has occurred along these routes, mostly replaced by commercial and subsistence agriculture. Deforestation was positively correlated with the distance from roads and villages while negatively correlated with the park boundaries and elevation (Liu et al., 2016). Lim et al., (2017) also asserted that infrastructure development, mainly roads and bridges creating networks were a key proximate cause of Myanmar's forest loss or degradation. Studies related to deforestation and forest degradation in Myanmar such as Htun et al., (2013); Lim et al., (2017); Mon et al., (2011); Rosy Ne et al., (2009) and Shimizu et al., (2017) confirmed that road construction, which promoted network accessibility across the Myanmar's remaining unspoiled forests, have contributed to forest loss and degradation. Htun et al., (2013) reported that forest cover loss and degradation was more severe in the areas close to main roads and park tracks of the Popa Mountain Park. Fuelwood collection was likely to be a significant driver of deforestation and forest degradation in the Popa mountain park, central Myanmar. Women and children mainly performed the fuelwood collection in the region. As a consequence, forest areas adjacent to roads and park tracks that are easily accessible were more impacted and degraded.

Putz, Dykstra, & Heinrich, (2000) reported that almost all selective logging procedures in the tropical forests worldwide are inadequately planned and often create the excessive road-construction activities in natural settings. This access allows resource hunters and forest penetration into frontier tropical forests. These actions have compounded deforestation and forest degradation due to selective logging operations in those areas (Laurance et al., 2009). Logged forests in the Amazon penetrated by logging roads are approximately 400% more likely to be deforested than un-logged forests (Gregory et al., 2006). Similar conditions were observed in Myanmar's tropics. Win, Mizoue, Ota, Wang, et al., (2018) have shown that illegal logging for both timber and charcoal increased notably after legal operations. Temporary logging roads by legal operations were used by illegal loggers who previously had no access. Although these roads are closed according to Myanmar forestry rules, Win et al., (2018) confirmed that most of the logging roads within the study area were easily accessible to illegal trucks. Mon et al., (2011) and Khai et al., (2016) also reported the similar processes and patterns of deforestation and forest degradation within selectively logged forests. Therefore, the government should enforce the forestry rules for closing the temporary logging roads and bridges efficiently after the legal operations.

Worldwide, road infrastructure is known to be an important driver of the spatial pattern of forest loss and subsistence agriculture (Allen & Barnes, 1985; Lambin et al., 2001 and Laurance, Goosem, & Laurance, 2009). The nature of forest cover loss due to road construction is complex (Laurance, 2009). Forest encroachment and destruction have usually followed with the construction of roads, even in remote areas. Secondary roads that increase the spatial scale of main roads were also developed. These expanded road networks have posed many environmental problems such as forest fragmentation and road fauna kills in tropical forests (Laurance & Balmford, 2013). Pfaff et al., (2007) claims that road networks in the Brazilian Amazon region significantly shape the remaining spatial pattern and the extent of tropical forests. Whenever new road investment occurred, the neighbouring forest clearing within 100 km increased. Road density is significantly correlated not only with market access, economic development but also natural resource exploitation, habitat fragmentation and deforestation in the Congo basin (Wilkie, Shaw, Rotberg, Morelli, & Auzel, 2000). Moreover, paved or unpaved roads and highways play a role in opening up access to natural areas for resource hunters and forest invasions. Laurance et al., (2009); Nepstad et al., (2006) and Pfaff et al., (2007) suggested that protected areas (PAs) could be created in advance along the new planned roads to reduce the uncontrolled forest loss and invasion. Therefore, the establishment of the protected areas along the new road development, especially in well-forested areas, should be prioritized in Myanmar where the Aichi Target 11 of the Convention on Biological Diversity (CBD) has not yet been met (FD, 2015). The Aichi Target 11 is a commitment by members of the United Nations (UN) to commit to conserve at least 17% of the countries terrestrial and inland water area and 10% of coastal and marine areas, especially areas with higher biodiversity values and ecosystem services, by 2020 (IUCN, 2016).

4.1.5 Mining sites and dam construction

Myanmar is one of the largest nations in Southeast Asia and has a wide array of mineral resources including popular jade, gemstones, gold, silver, copper, tin, and tungsten (Gardiner, Robb, & Searle, 2014). However, the country's mineral resources have been poorly explored and the mining sector was underdeveloped during the era of the military dictatorship. Under the democratic government, foreign investment in Myanmar has focused on the mining sector. A recent remote sensing based study of the extent of mining in Myanmar between 2002 and 2015, states that over 90 thousand hectares of new mine sites were identified across Myanmar (Connette et al., 2016). Most of these mining areas were observed within densely forested areas. Of which, about 71% are concentrated in the Sagaing region and Kachin state that has significant gold and jade deposits. The third largest mining areas occurred in the Mandalay region, followed by Shan, Tanintharyi, and Bogo. The development of tin mines in Shan along the border with China has increased Myanmar's share for the global tin market (Connette et al., 2016). Mining has been conducted by both legal and illegal operation, ranging from small scale to large open-pit mines (Takahito, Yuichi, Osawa, & Hatsukawa, 2015). A study of gold mining and agricultural expansion impacts on tree cover and local communities in the northern part of Myanmar, with evidence of a spatial association between the gold mines and tree cover loss (Sarah et al., 2017). Tejas et al., (2017) claims that open-pit mining in the northern part of Myanmar has contributed to major intact forest loss during the 2002 - 2014 study period. These sites were often observed along the rivers and streams. Contaminates, such as mercury used for mining, are discharged into waterways and have negatively impacted on local communities and biodiversity. Therefore, mining in Myanmar which is expected to continue to grow might impact not only on the intact forests in remote areas but also on biodiversity and local communities.

Global population growth, economic development, and industrialisation over the past four decades have increased the demand for energy. That demand has led to the expansion of hydropower projects and dam construction across the world (Jiang et al., 2018). Such demand has also occurred in Myanmar and Changjian Wang et al., (2013) estimate that 48 hydropower projects were operating or under construction in Myanmar. Most of these are located in the densely forested areas with higher biodiversity values. Shimizu et al., (2017) also found that water invasion was the second largest disturbance (14.6%) of deforestation after logging (59.8%) in the Bago mountain region. Water invasion is attributed to dam construction over the past 15 years. Forests in most of the study areas (26 townships) were impacted by water invasion due to dam construction, with large forested areas logged before dam construction. This suggests that the construction of dams in Myanmar has negatively impacted on the forests. Likewise, the impacts of dam construction on deforestation and forest degradation have long been recognised (Chen, Powers, de Carvalho, & Mora, 2015 and Jiang et al., 2018; Lees, Peres, Fearnside, Schneider, & Zuanon, 2016). However, to this point, dam construction and its impact on the environment has been under-researched in the Myanmar context. Therefore, the area is worth further attention given the impact of dam construction on forest loss and degradation in Myanmar.

4.2 Insight into Possible Policy Interventions

The drivers of deforestation and forest degradation in Myanmar are complex, having socioeconomic, demographic, and political implications. For some time, it has been recognised and suggested that Myanmar requires a reform process to control unsustainable natural resource exploitation (Donald et al., 2015; Springate-Baginski et al., 2014). Since the election of the democratic government in 2015, the country has been better connected with international communities and access to global markets. Subsequently, foreign investment has improved various sectors, and often based on natural resource extraction (Gardiner et al., 2014; Changjian Wang et al., 2013). Therefore, Myanmar's remaining biodiversity rich forests have been impacted and are likely to be more impacted in the near future, highlighting a need for environmental conservation measures.

Globally there is an awareness of the importance of the role of protected areas (PAs) for natural resource and biodiversity conservation (Scharlemann et al., 2010). Researchers in the field have encouraged the conservation of biodiversity rich areas within PAs. In Myanmar, according to the National Biodiversity Strategy and Action Plan (2015-2020) (NBSAP), forests within the Permanent Forest Estate (PFE) are managed by MONREC (FD, 2015).

Forests are categorised into three groups either for timber production (reserved forest - RF), supply forests for local communities (protected public forest - PPF), or wildlife conservation (protected areas - PAs). Forests outside the PFE may be classified as public forests or unclassified. In 2015, ~ 30% of the country's area had been designated within the PFE (FD, 2015). Moreover, Tejas et al., (2017) reported that a higher proportion of Myanmar's remaining densely forested areas are not protected either within the nation's reserve forests or PAs. These forests are unclassified forests according to FD. Most of these areas are located in the mountainous upland areas of the country where historically conflicts between the ethnic armed groups and military have occurred. Thus, it was difficult to designate those areas as PAs from the union government, although all the trees in the country whether within or outside the PFE are subject to the regulations of the MONREC (FD, 2015 and Myint Aung, 2007). Under the PFE, settlements and harvesting are not allowed. All the PAs in Myanmar are currently managed by the Nature and Wildlife Conservation Department (NWCD), which is a section under the FD. Myanmar has now declared 6.37% (42878 km^2) of the total land area as terrestrial and inland water PAs and 2.33% (11964 km^2) for marine PAs (UNEP, 2019). According to the NBSAP report, Myanmar plans to conserve up to 8% by 2020 and 10% by 2030 of the country's terrestrial area. This means that Myanmar still requires almost double the current designated areas to meet the Aichi Target 11 of the CBD, to designate 17% of the country terrestrial and inland water area as PAs. Therefore, it is highly recommended that more PAs are declared in Myanmar. Moreover, it has been suggested that these declarations occur in advance of new road construction especially in the frontier areas (Laurance et al., 2009). In Myanmar, there have been 132 keys biodiversity areas (KBAs) identified by the Wildlife Conservation Society (WCS) (FD, 2015). However, just 35 KBAs are being protected within current PAs and still more KBAs are likely to be identified. Hence, speeding the designation of PAs in Myanmar seems to be important for both meeting the CBD commitments and covering all KBAs. Australia provides an example of what might be achieved. In 1997, the Australia government developed the National Reserve System to meet CBD targets, building the Collaborative Australian Protected Area Database (CAPAD) to record and keep track of PAs across the nation (Cook, Valkan, Mascia, & McGeoch, 2017). Moreover, PAs in Australia can be designated by either State or local government (James, 2015). Remarkably, the percentage of terrestrial PAs almost doubled from 7.5% in 1997 to 15.9% in 2014 (Cook et al., 2017). In Myanmar, therefore, with the new democratic government, it is suggested to reduce the central government control by sharing the power to state and regional governments for establishing PAs within their state or region. Moreover, as mentioned above, most intact forests in the uplands where ethnic communities live are not yet designated as PFF that are governed by the central government, and hence it would be an opportune time to step forward by reducing centralisation in natural resource management in those areas.

Another important point is that greater community involvement in natural resource conservation has provided better results in forest protection across the world (Reed, 2008). However, in Myanmar, historically science-based forestry management started during the British colonial era, which targeted revenue and marginalised by a focus on wood extraction (Springate-Baginski et al., 2014). This focus on resource utilisation with limited community involvement continued through the military lead government era until the present day.

However, it has been widely accepted that forest resources can contribute to the livelihoods of local people, particularly in developing countries (Rasmussen, Watkins, & Agrawal, 2017). In Myanmar, about 70% of the population live in rural areas and rely on natural forest resources, not only timber but also other forest products such as fuelwood and bamboo. Moreover, forest dwellers who live near or in the forest have been practicing traditional shifting cultivation, which is a common practice of subsistence agriculture in Myanmar, since before the colonial time (Bryant, 1994). However, it was reported that shifting cultivation in Bago mountains has contributed to forest degradation but resulting in only low levels of deforestation (Rosy Ne et al., 2009). Thus, having a great number of people relying on natural forest resources, local involvement in the forestry management would have a better impact on sustainable natural resource conservation in Myanmar.

With increased recognition of the importance of community involvement in natural resource management, community forestry (CF) has emerged in Myanmar in the past few decades (Feurer, Gritten, & Than, 2018). The FD has set a target of 919,000 ha for CF management by 2030, and 12% of this target was achieved by 2016 (Feurer, 2018). As of 2017, 3840 community forestry user groups across the country have registered with the FD. However, Lin, (2004) has raised criticism of the CF program in Myanmar, which has suffered from setbacks due to a lack of secure land tenure and local engagement. Moreover, a study related to the benefits of CF for livelihoods in Myanmar’s mangroves (Feurer, 2018) suggests that trust building between the communities and the government, especially to make more secure for forest land tenure is critical for the CF development in Myanmar. Therefore, efforts to encourage greater involvement of rural communities should be investigated and land tenure policies strengthened through stakeholder analysis to address these issues.

On the other hand, timber industry has been influenced by illegal markets in both the domestic and export sectors. The present wood trading industry has emerged from the foreign income targeted policy of the military led elite groups (Springate-Baginski et al., 2014). The democratic reform process requires a change from the predominance of past players to more an open market system to reduce corruption in the system. Enforcing the rule of law in the forestry sector is important to combat illegal logging and related corruption. Knowing the consumption rate of wood for both timber and fuelwood in Myanmar will support the change process. Nevertheless, local wood consumption and demand data are very limited and unreliable and subsequently require further attention and research (Springate-Baginski et al., 2014).

5. Conclusion

The study applied 2005, 2010 and 2015 land cover maps derived from remote sensing images supplied by the FD, Myanmar to understand the patterns and rates of deforestation and forest degradation. The results showed the overall annual forest cover loss rate to be 2.58% between 2005 and 2010, and 0.97% between 2010 and 2015. The change detection analysis shows that the forest cover change pattern occurred through forest degradation to deforestation. This has been confirmed by other remote sensing and field observation-based studies (Treue et al., 2016 and Tejas et al., 2017). Therefore, over-logged areas are often followed by further encroachment for charcoal and fuelwood production and then can shift towards permanent conversion as either agriculture or plantations. Such a pattern has occurred across the country. The major forest cover changes were found in Kachin, Shan, Tanintharyi, and Sagaing where most of the agricultural expansion and wood extraction has occurred. The literature, official reports, and websites were then explored to uncover the issues behind forest loss in Myanmar. Given a greater understanding of these issues, some insights into policy interventions have been provided. The first insight would be to work towards strengthening the PA system in Myanmar, where the KBAs have not yet been protected. In doing so, it will help to achieve an international commitment to meet the CBD targets for biodiversity conservation. The second proposition from the work would be to emphasise community participation in forestry management although it is already a prioritised area of FD. The work suggests that more involvement of multi-stakeholders such as CSOs and NGOs, in addition to local communities may be beneficial. The third insight from the work suggests that a reduction in centralisation of forestry management by sharing responsibilities with the local government may be timely with the emergence of the new democratic government. The fourth suggestion would be to encourage movement away from corruption related wood trading industry in the country through the formation of local based small and medium enterprises. Lastly, remote sensing and GIS are powerful tools that can help to better manage the forest areas and therefore, capacity building and human resource development relating to these areas should be encouraged. Forest cover mapping using remote sensing derived images for the production of higher quality maps with reliable ground-truthing accuracy assessment is recommended as a future research area.

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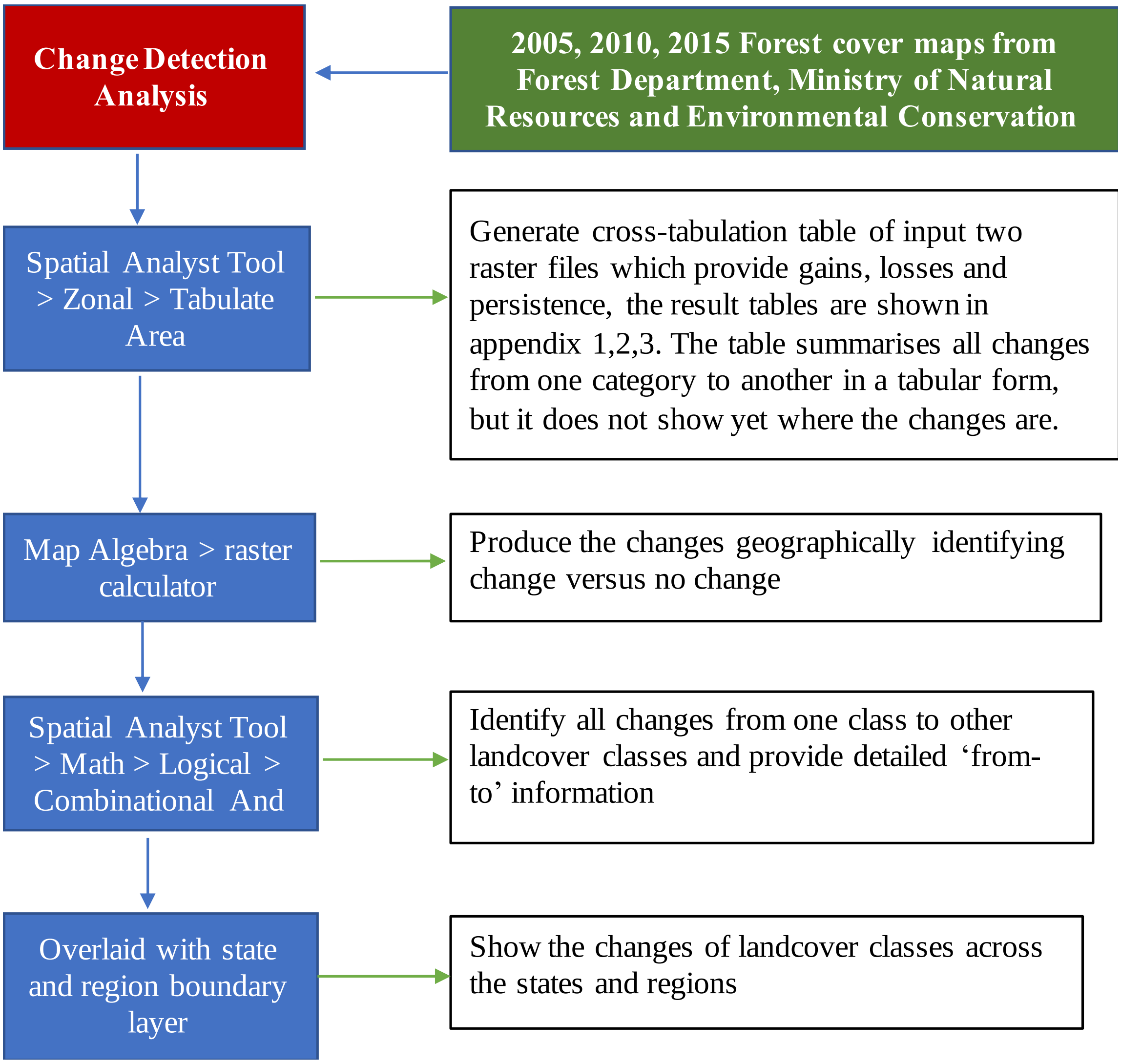
Appendix

Appendix 1: Flow diagram of change detection analysis GIS work.



Appendix 2: General cross-tabulation matrix of two maps at different points in time.

Time 1	Time 2				Total time 1	**Loss**
	Category 1	Category 2	Category 3	Category 4		
Category 1	P_{11}	P_{12}	P_{13}	P_{14}	P_{1+}	P_{1+} - P_{11}
Category 2	P_{21}	P_{22}	P_{23}	P_{24}	P_{2+}	P_{2+} - P_{22}
Category 3	P_{31}	P_{32}	P_{33}	P_{34}	P_{3+}	P_{3+} - P_{33}
Category 4	P_{41}	P_{42}	P_{43}	P_{44}	P_{4+}	P_{4+} - P_{44}
Total time 2	P_{+1}	P_{+2}	P_{+3}	P_{+4}		
Gain	P_{1+} - P_{11}	P_{2+} - P_{22}	P_{3+} - P_{33}	P_{4+} - P_{44}	1	

* Diagonal line highlighted in green colour represents persistence between two different points of time.

Appendix 3: Magnitude and rates of landcover changes during study periods.

LC Classes	**2005 Area(Mha)**	**2010 Area(Mha)**	**2015 Area(Mha)**	**2005-2010, change rate (r ,%/yr)**	**2010-2015, change rate (r ,%/yr)**	**2005-2015, change rate (r ,%/yr)**
Closed Forest	19.6	14.9	12.5	-5.44	-3.54	-4.49
Open Forest	15.9	16.3	17.2	0.45	1.12	0.79
Total Forest	35.5	31.2	29.7	-2.58	-0.97	-1.78
Mangroves	0.52	0.51	0.48	-0.19	-1.58	-0.89
Other woodland	12.8	14.0	18.9	1.90	5.98	3.94
Others	16.9	19.7	17.0	2.98	-2.93	0.02
Water	2.1	2.7	2.0	4.60	-5.89	-0.65
Snow	0.3	0.1	0.1	-12.95	-1.31	-7.13