FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 4 No. 2, June, 2020, pp 767 – 779
DOI: https://doi.org/10.33003/fjs-2020-0402-449

KEY DRIVERS OF DEFORESTATION IN PEHANG MALAYSIA: A THREAT TO TROPICAL FOREST ECOSYSTEM

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ABSTRACT
The growing population is often associated with various environmental disturbances which have been altering the natural earth ecosystem and numerous land development activities have made the existing forests suffer deforestations. The aim of the research is to ascertain the key drivers of deforestation. The techniques employed are landsat TM, SPOT-5 and land use map. Deforestation rates between 1990 and 2010 indicated total deforestation occurred between 1995 and 2000 of 7.59% at a rate of 0.04 ha/year, follow by the year 2005 to 2010 with 6.74% at a rate of 0,032 ha/year. The lowest deforestation was recorded between 1990 and 1995 with 0.38% at a rate of 0.002 ha/yr while the total deforestation for the entire 30 years was 16.98% at an average rate of 0.020 ha/yr. The deforestation rates in Pahang have been estimated to occurred between years 1990 and 2010 ranging from 0.002 - 0.04 million ha/yr. These results demonstrated that Pahang is still characterized by high forest cover and slow deforestation rates. However, commercial agriculture was estimated to be the first single driver of deforestation, which accounted for about 80% of deforestation compared to other drivers. The finding concluded that commercial agricultural such as palm oil plantation and rubber plantation was the main proximate drivers for the deforestation in Pahang. It was demonstrated that the integration of multi temporal datasets from Landsat-TM and SPOT-5 satellite images with landuse maps was capable in identifying direct drivers of deforestation. However, extensive use of ground thruting will compliment the landsat, SPOT-5 and the landuse map.

Keywords: Agriculture, Deforestation, Drivers, Forest, Plantation.

INTRODUCTION

Deforestation is defined as the felling of trees without subsequent replanting or regeneration, the conversion of previously forested land to agricultural, urban or other land uses, which do not have a substantial tree canopy cover < 10% (FAO, 2011). Statistically, about 1 to 2 billion tons of carbon per year which is equivalent to 15 - 25% of annual global greenhouse gases (GHG) emissions arises from tropical forest deforestation and degradation (Houghton, 2005;Gibbs et al., 2007). The conversion of existing forests to non-forest areas will increase GHG emissions which could lead to the global climate change (Houghton et al., 2000). However, emission figures do not recognize the effect of degradation that occurs in forests due to selective logging and fires (Achard et al., 2014). Land degradation and loss of Malaysia's original forest have resulted from rapid logging and conversion of land for agricultural purposes (Gillis and Repetto, 1988) and the forest had decreased by 1.2 million hectare by 1990 (FAO, 2011). Half of the forests in the Peninsular Malaysia witnessed forests cleared in the late 1980s (Gillis and Repetto, 1988), as this decreased the total forest cover to 57% of the original area by 2002 (Langner et al., 2007). This has resulted in a serious land cover challenge in the Peninsular Malaysia (Brookfield & Byron, 1990). Deforestation can play a role in global warming and cooling, as well as reducing biodiversity, disrupting water management, and damaging the resource base and livelihoods of many of the world's poorest citizens (David et al., 2010). Likewise forest clearing causes an abrupt land-use change and typically causes larger carbon emissions per hectare (Watson et al., 2018). Reducing deforestation would therefore not only reduce greenhouse gas (GHG) emissions, but would also provide additional benefits to the climate system. This includes preserving the net carbon sink that may be present in old-growth tropical forests, and the evapo-transpiration and rain- and-cloud formation function that cools the tropics and maintains rainforest extent. Moreover, tropical forests host over half of all global biodiversity, and their preservation is essential for maintaining the richness of life on Earth (Angelsen et al., 2001). It is not an easy task to address this problem as researchers need to figure out how to keep a significant amount of natural forest carbon stocks stored in their stems, leaves and roots from being emitted into the atmosphere. Therefore, one way to determine the extent of deforestation is identifying the drivers (or factors) of the deforestation such logging, subsistence agriculture, large scale agriculture and pasture, plantation and dams (Gibbs et al., 2010).

Multi temporal optical remote sensing system has been used in identifying landuse changes in the last few decades. The system offers specific advantages, challenges and limitations for producing reliable estimate at a given scale (Lillesand and Kiefer, 1994) and also the techniques offer benefits for monitoring forest degradation in areas with difficult access, such as rainforest regions (Herold and Skutsch, 2011). Likewise landsat was use in studying the primary source of deforestation in the Tropical forests and the result indicated croplands, pastures, and temporary agriculture increased by 629 million ha while developed countries lost 335 million ha (Alexandratos, 1999). Similarly, Gibbs et al., (2010) used landsat technique in identifying rate of deforestation in southern east Asia which the results reveal that, more than 55% of this new agricultural land came from intact forests. However the combination of landsat and spot-5 satellite images which has a high resolution and covering wide range can be better applied in identifying drivers of deforestation in Pahang. The specific objective of this study is to identify the key drivers of deforestation in Pehang Malaysia from the multi-temporal land use and land cover data of the study area (between 1990 to 2010) with a view to establishing the extent

and trend of deforestation.

MATERIALS AND METHODS

The Study Area

Pahang is the largest state in Peninsular Malaysia with a total area of 36,137 km^2 and is situated in the eastern coastal region (Fig 1). It is located between 27^{0}47′99″N and longitude 43^{0}76′90″E with total forest cover of 1,562,902 ha. The state is bordered by Kelantan in the North, to the West by Perak, Selangor, Negeri Sembila, to the South by Johor and to the East by Terengganu and the South China Sea.

The overall vegetation type in Pahang National Pahang is lowland dipterocarp forests in which is characterized by high proportion of species in the family of Dipterocarpaceae with Meranti (Shorea spp.) and Keruing (Dipterocarpus spp.) as the dominant species (Appanah, 2000).Climate, soil, and soil water are the main interacting environmental factors that influence the distribution of plants and vegetation. Pahang has a climate that is rather uniform throughout the year. It is generally regarded as perhumid (i.e., wet throughout the year) with short dry periods. The rainfall patterns are determined by two alternating yearly monsoons: the Monsoons, North-East and South-West. In contrast to the south-west, the annual north-east monsoon brings a larger amount of rain. In Peninsular Malaysia, the mean annual rainfall is approximately 2,540 mm (Tjia, 1988).

Changes in temperature resulting from altitude changes are the only significant effect on temperature, with a decrease in temperature of 6.5 ° C with a rise in altitude per 1 km. The regular temperatures in Cameron Highlands, Pahang (at 1,450 m a.s.l.) average a minimum range of 13-14 ° C and a maximum range of 22-23 ° C, (Saw, 2010).

Forests in Pahang

A forest must have at least with 30% crown cover, with the minimum area spanning 0.5 ha and the minimum stands height of 5m at maturity (NRE 2014). Despite the forest being a crucial component in the global carbon cycle and having potentially profound influence on climate change, the areal extent of forests has declined significantly as a result of coastal development, aquaculture expansion and over-harvesting. Pahang, which is the largest state in Peninsular Malaysia was selected as the study area. Despite the largest state, currently Pahang has only about 1,562,902 ha of permanent forest. The Permanent Reserve Forest is designated for protection purposes such as Virgin Jungle Reserve (VJR), land protection areas, water catchments, flood control areas, wildlife protection, education, research and amenity forests. It cover an area of about 24,043 ha (Table 1).

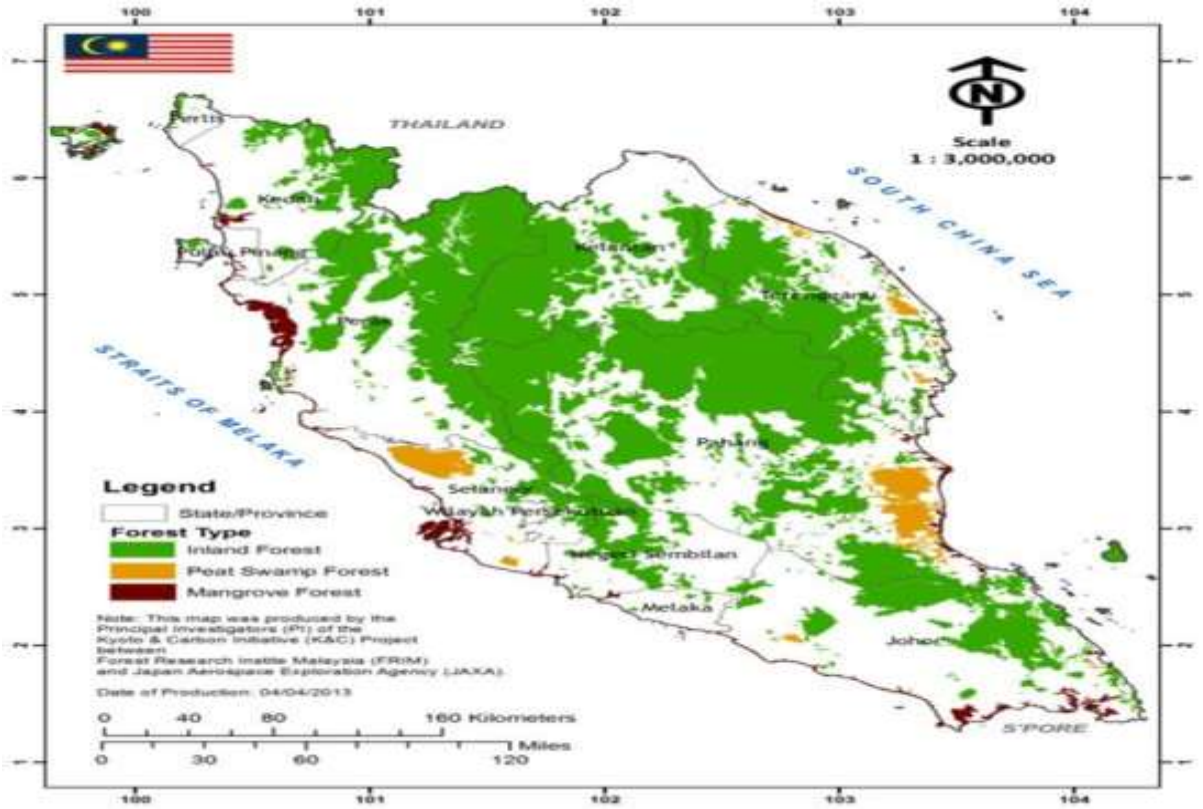


Figure 1: The Geographical Location of the Study Area
Source: Author, 2010

Table 1. Permanent Reserved Forest (Pahang) - 2012

State	Inland Forest (ha)	Peat Swamp Forest (ha)	Mangrove Forest (ha)	Forest Plantation (ha)	Total Area (ha)
	(a)	(b)	(c)	(d)	(e)=(a+b+c+d)
Pahang	1,395,613	140,830	2,416	24,043	1,562,902
	1,506,443				
	Production 714,182 (45.4%)	**Protection** 822,261 (54.6%)			

METHODS OF DATA COLLECTION AND ANALYSIS

In this study, the land use and land cover (LULC) in Pehang Malaysia between 1990 to 2012 was determined using Landsat-TM and SPOT-5 satellites images (Yosio et. al., 2019). Landsat data over the year 1990 – 2005 were downloaded from US Geological Survey National Center for Earth Resources Observation and Science via the GLOVIS data portal (http://glovis.usgs.gov/) with relatively cloud cover less than 30%. At least four individual scene of Landsat images are required to cover the entire Pahang for a year and the path/row numbers for the scenes are 126/057, 126/058, 127/057, and 127/058. Therefore, 20 were acquired to complete the years of 1990 – 2005, whereas for year 2010, SPOT-5 satellite image was used (Yosio et. al., 2019).

The digital land use map and topographic maps was used to estimate the changes in forests cover area between 2000 and 2010. This was follow by verification using ground thruting.

RESULTS AND DISCUSSION

Deforestation and Forest Cover Changes in Pahang

Deforestation refer to as human induced permanent conversion of forest land to non- forest, as all of the forest is cut and the land is cleared and used for another purpose. Temporary change in land use, like one rotation tree crop (up to 25 years) within forest reserves are not considered as deforestation (NRE 2014). Pahang total land area has being estimated to be about 3.6 million ha with an overall forest cover stood at 2.5 million ha in the year 2000 (Fig 2). There were great changes in forests area in Pahang between 2000 and 2010.

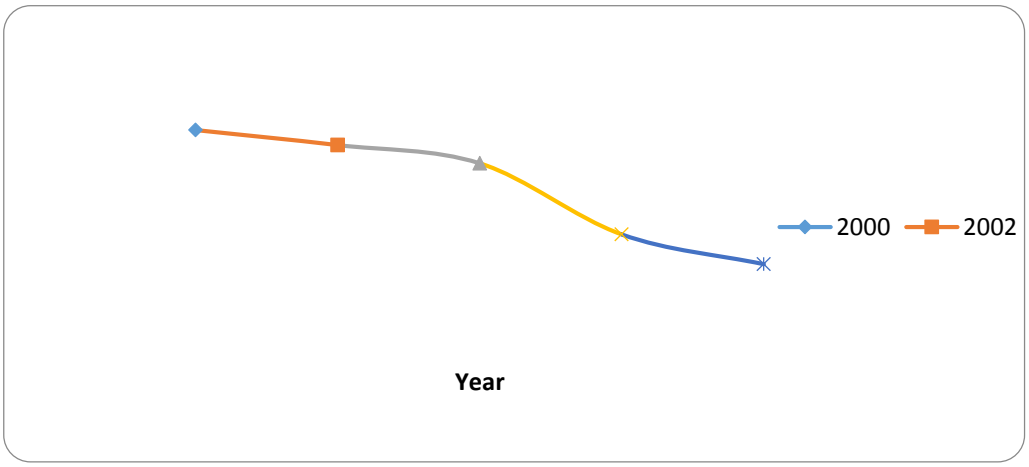


Figure 2: Forest cover
Source: Author, 2010

Forest Cover and Forest Cover Change Using Satellite Images

Landsat TM and Landsat ETM images were obtained from Remote Sensing Agency Malaysia (Fig 3). SPOT-5 satellite data were also obtained with relatively cloud cover of less than 30% (Fig 4). The methodology was based on two main approaches; (i) images classification for landuse types and (ii) post-classification for change detection. Images for each year were classified to determine landuse classes in the study area. Forest cover was definitely the single class that was extracted first from the classification (Fig 5). Other landuses such as agriculture crops, urban areas, water bodies, and open lands were also classified. The classification accuracy was done by

cross-checking with landuse maps that were obtained from the Department of Agriculture. The classification results were then converted to vector format to perform post-classification change detection. Changes were determined from this process for each pairing interval of 1990-1995, 1995-2000, 2000-2005, and 2005-2010. Rate of deforestation as well as drivers that caused the forest changes were identified and quantified within each interval.

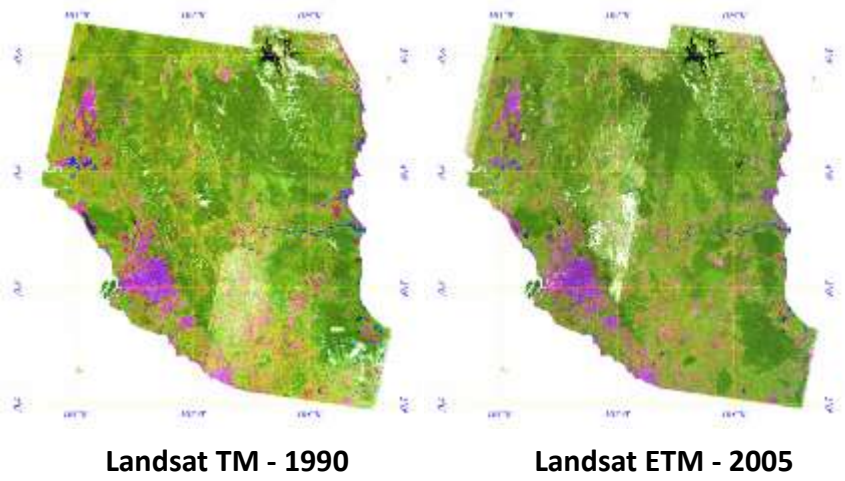


Figure 3 Landsat Images
Source: Author, 2010

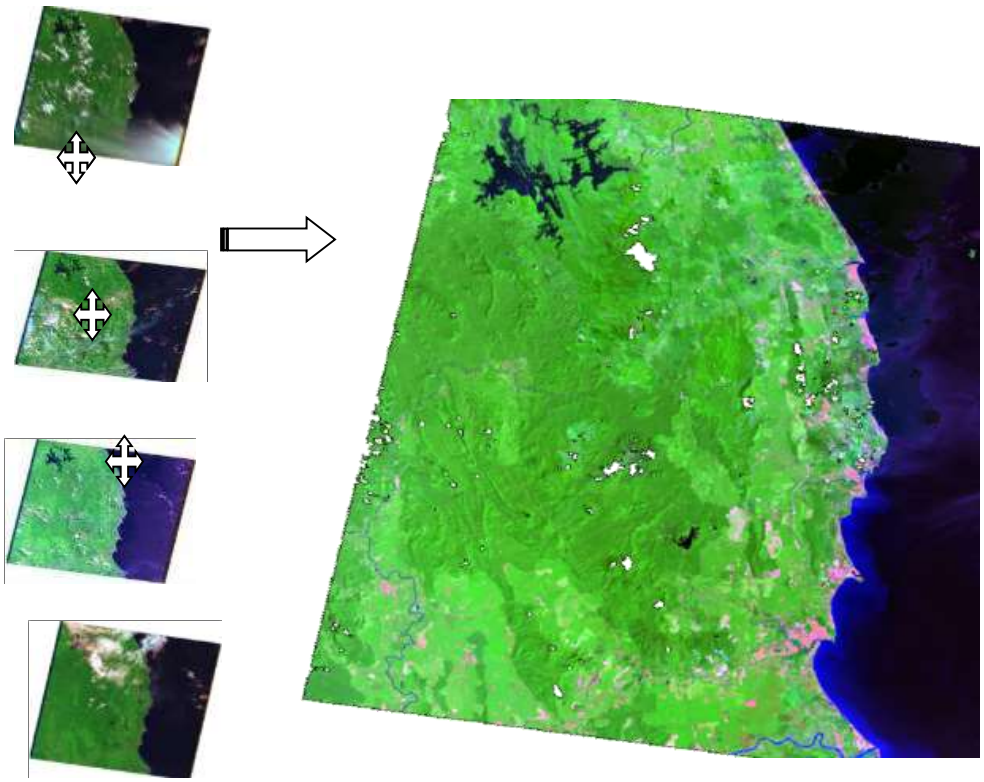
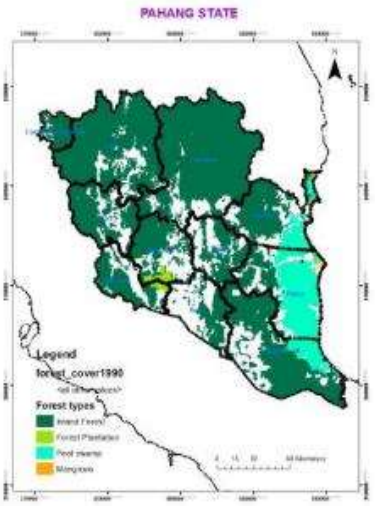
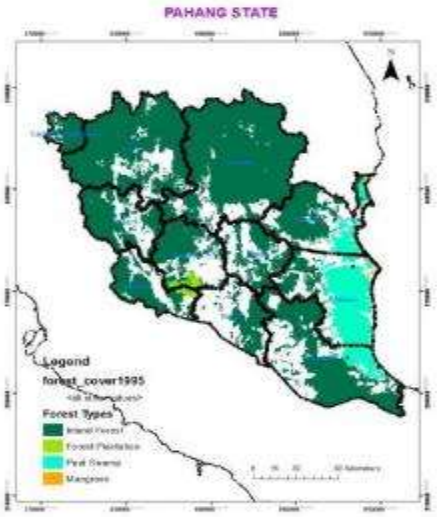


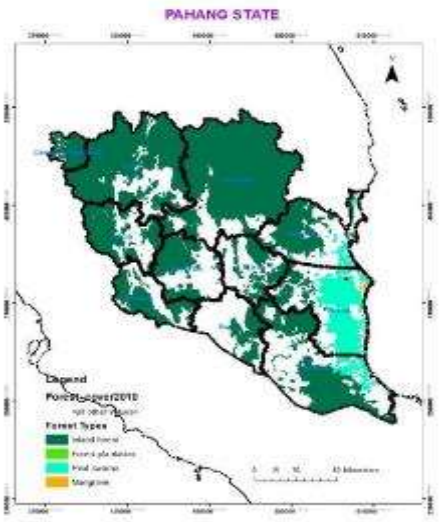
Figure 4: Cloudless Landsat mosaics
Source: Author, 2010



Forest Cover 1990

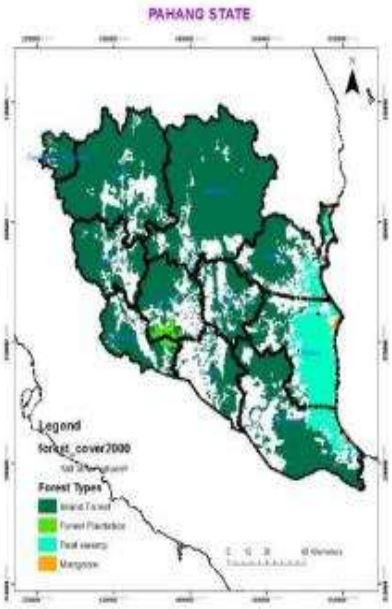


Forest Cover 1995

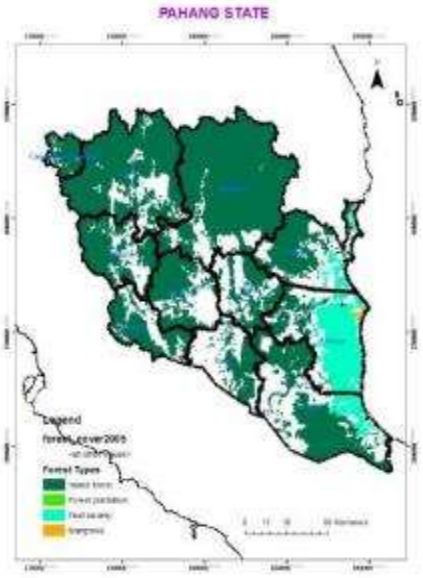


Forest cover

Forest Cover 2010



Forest Cover 2000



Forest Cover 2005

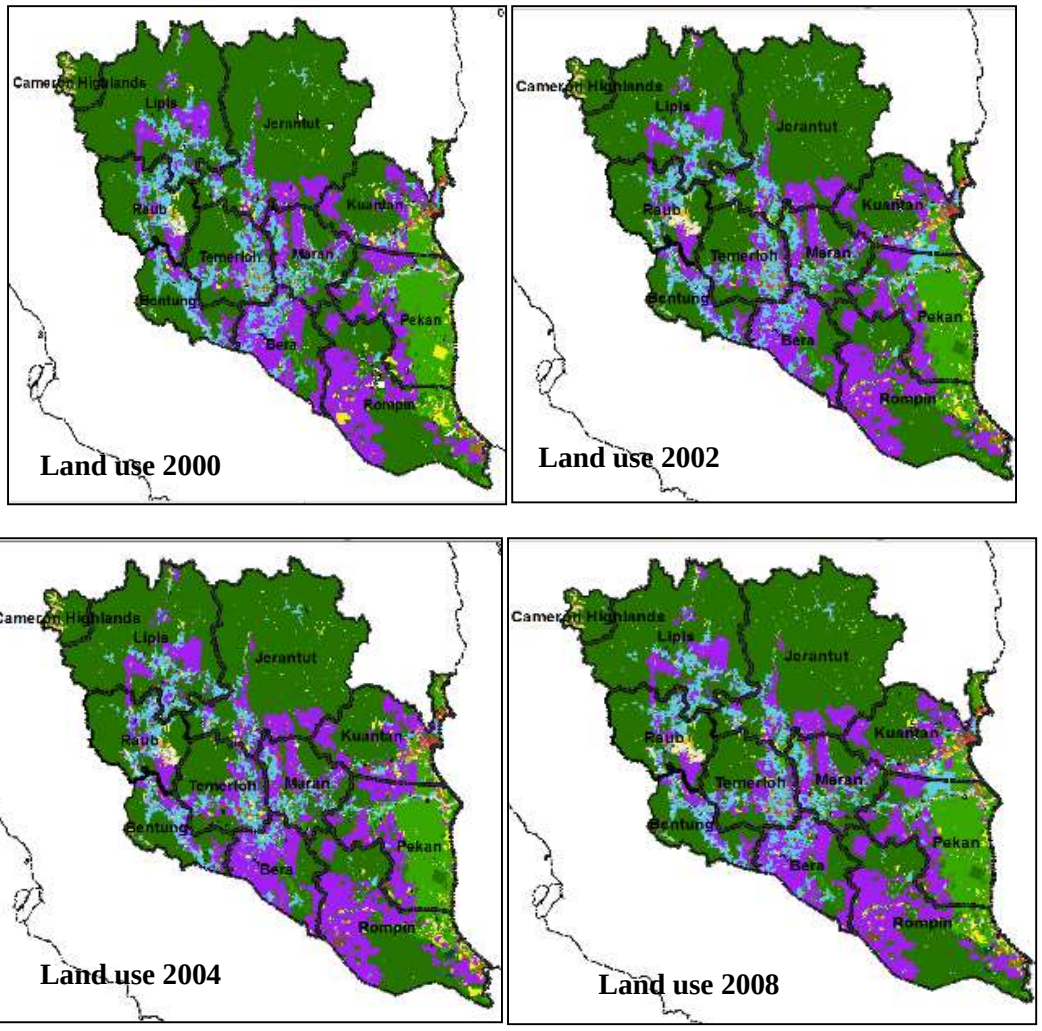
YEAR	Area (Ha)
1990	2,633,065.8
1995	2,623,992.3
2000	2,424,921.9
2005	2,344,228.3
2010	2,186,178.8

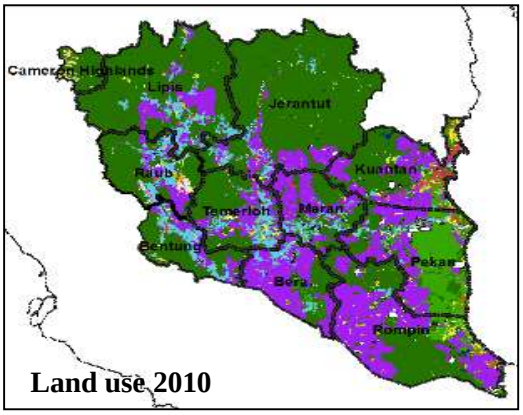
Figure 5: Forest Cover using Satellite Images
Source: Author, 2010

Forest Cover and Forest Cover Change using Land Use Map

The land use map indicated changes in forests cover area between 2000 and 2010 due to various land use activity and the rate of deforestation was indicated using the land use map to occurred between 2000 and 2010 (Fig 6). The composition of land use categories involved oil palm plantation, rubber plantation, urban area, agriculture area, water body, mine and quarry, idle grassland, animal husbandry areas and cleared land (Fig 7). The changes in land use in Pahang using land use map show a clear trend of deforestation from 2000 to 2010.

Land use map showed a decline in forest cover between 2000 and 2004 and sharply decline from 2004 to 2010. The forest covers depict a clear change between the year 2000 and 2002 as land use was responsible for the changes. Land use such as oil palm and rubber plantation were found to occurred in over 12644 and 10720 ha of the land cover, subsequently follow by agricultural activity, idle grass land, clear land, urban area. Between the periods of 2002 to 2004 there were few changes as oil palm increases to about 23870 ha while rubber deceased by 1292 ha with changes in other land uses. Based on FAO 2006 statistics which was similar to the land use map analysis, it was been estimated that the land use rate in Pahang for the period 2004 to 2008 has increased and the changes involve the increases in oil palm, rubber, agricultural activity, land clearing, urban area and mining and quarry activity with the rapid changes recorded in land clearing. Between 2008 and 2010 total oil palm and rubber cover is estimated to have stood at 17212 and 7361 ha higher compare to previous years. There was slightly increased in urban area, agriculture while animals husbandry and mining activities reduces. Cumulative forest changes resulted from drivers of deforestation recorded between 2002 to 2010, with a total cumulative recorded between 2000 to 2010 indicated high increase in oil palm, rubber plantation, land clearing, agricultural activity, urban area and subsequently follow by idle grass land, mine and quarry, water body and animal husbandry.





1. Forest
2. Oil palm
3. Rubber
4. Urban area
5. Agriculture
6. Water body
7. Mine and quarry
8. Idle grassland
9. Animal husbandry
10. Cleared land

Figure 6: Forest cover changes from Land Use Map
Source: Author, 2010

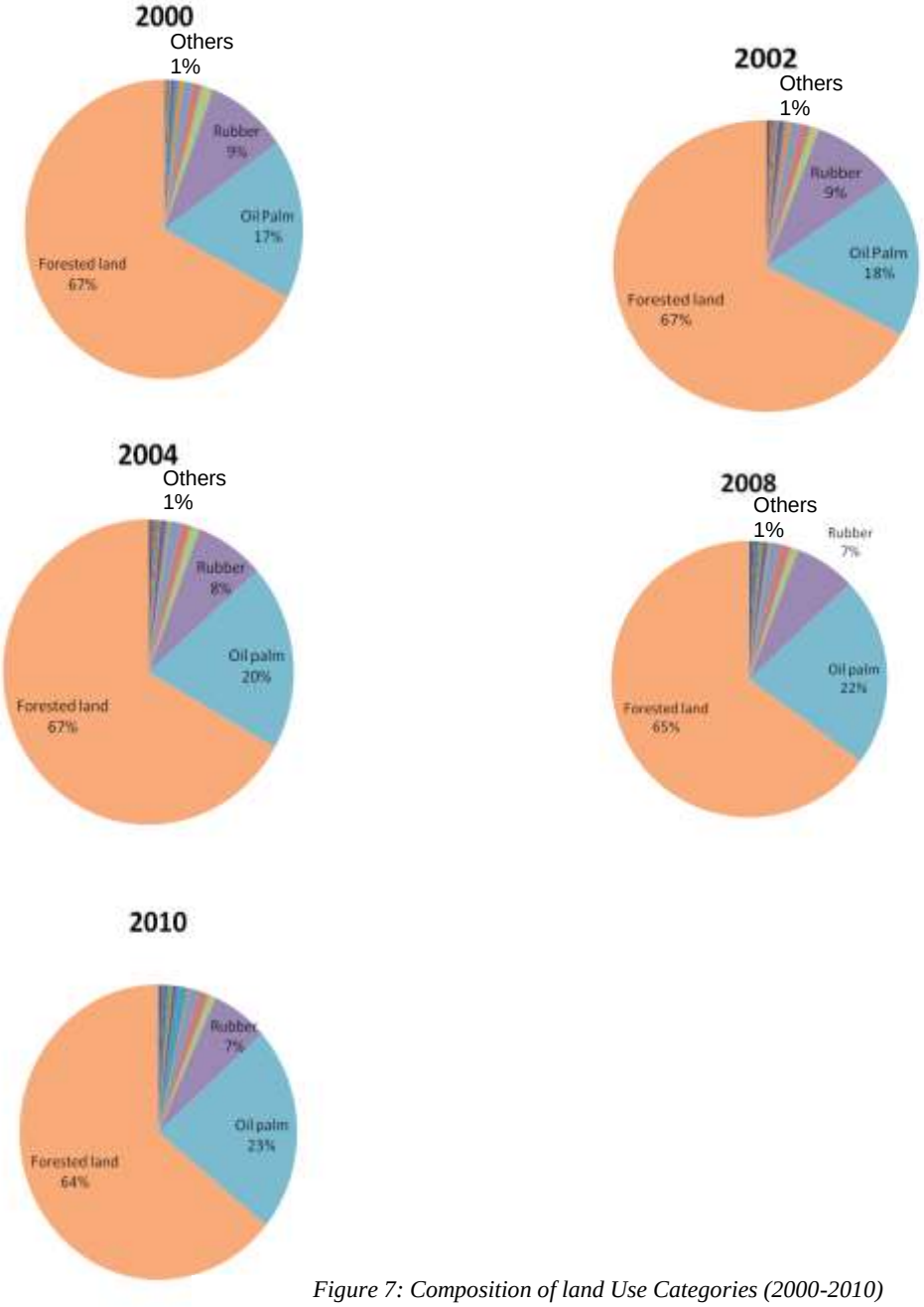


Figure 7: Composition of land Use Categories (2000-2010)
Source: Author, 2010

Trend and Rate of Deforestation using Satellite Data Analysis

Four series of temporal satellite images were acquired in the years 1990-1995, 1995-2000, 2000-2005, and 2005-2010 to complete the exercise. Landsat-5 TM, Landsat-7 ETM+, and Landsat-8 OLI satellite images for the respective years were utilized in this study. All images were geo-referenced to the Malaysia Rectified Skew Orthomophic (MRSO) projection system so that the series of images are registered in the same coordinate system and all were then processed to classify mangroves areas and separate them with the other land covers. The classification results were exported into vector format (shape file) to be refined and edited in GIS. The GIS platform was employed to execute post-classification processes. Changes were identified from post-classification change detection technique (Jensen, 2005). The changes in forests were identified due to rate of deforestation between 1990 and 2010 from the satellite images (Fig 8 & Table 2).

The general rate of deforestation based on the satellite images acquired indicated the average deforestation rate between 1990 and 2010 was recorded to occurred between 1990 and 1995 at 2.633 and 2.623 ha respectively, with the permanent forest reserve (PFR) maintaining a land cover of 1.42 ha from 1990 to 2000. However, there was decrease in deforestation between 2000 and 2010 and increase in PFR (Fig 8 & Table 2).

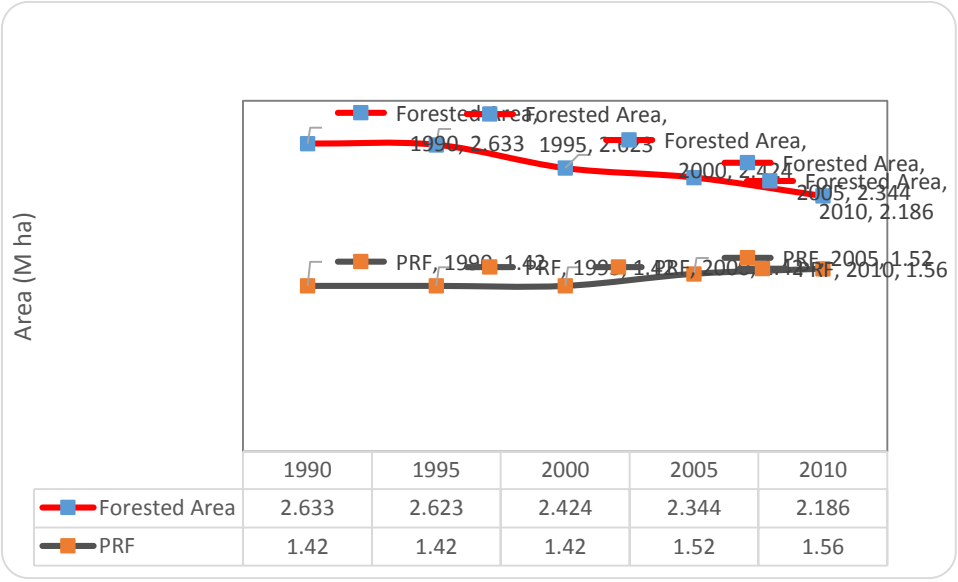


Figure 8: Trend of deforestation, 1990-2010
Source: Author, 2010

Table 2: Rate of Deforestation (1990-2010) from Satellite Images

Internal Years	Deforestation or Forest area change (ha) (%)	Deforestation rates (ha / yr)
1990-1995	10,000 (0.38%)	2,000
1995-2000	199,000 (7.59%)	40,000
2000-2005	80,000 (3.30%)	16,000
2005-2010	158,000 (6.74%)	32,000
		Rate of deforestation
1990-2010	**0.85% / yr**	**20,000 ha / yr**

Trend and Rate of Deforestation using Digital Map Data Analysis

Accessing the trend of deforestation from 2000 to 2010 using land use maps it indicated that deforestation was at its peak between 2000 and 2002 (Fig 9) similar to previous study, while PRF was low in 2000. Furthermore, the land use maps show a decrease in deforestation between 2008 and 2010 with increase in PFR between 2002 and 2010 which were similar to previous study. The rate of deforestation was found to increase from 2000 and attend it peak in 2010 (Table 3).

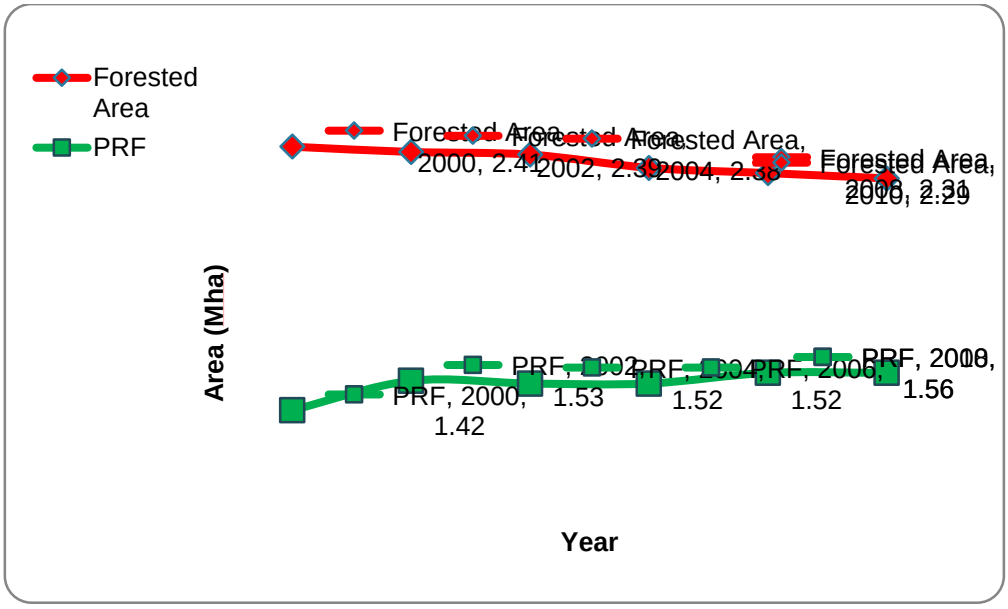


Figure 9: Trend of Deforestation (2000-2010) from Land Use Map

Source: Author, 2010

Table 3: Rate of deforestation (2000-2010) from Land Use Map

Year	2000-2002	2002-2004	2004-2008	2008-2010	2000-2010
Forest cover Changes (ha)	13,426.98	16,410.46	63,437.35	26,625.66	**119,900.45**
Rate of Changes (ha/yr)	6,713.49	8,205.23	15,859.3375	13,312.83	**11,990.05**
(%/yr)	0.28	0.34	0.67	0.58	**0.50%**

Key Drivers of Deforestation in Pahang

The results show that the forest cover of Pahang was about 2.633 million ha for the year 1990, which was around 73% of the total land use. The forest cover decreased to 2.623 million ha in 1995, which involved some 0.01 million ha of loss (or about 0.4% as compared to year 1990). The forests have continued to decrease in year 2000, with a depletion of about 0.199 million ha made up the forest cover left at about 2.424 million ha, which involved about 7.6% of loss. In year 2005, the forest cover declined again to 2.344 million ha a depletion of about 0.08 million ha (or loss of about 3.3 %) over the period between 2000 and 2005. However, the forest cover was last measured at 2.186 million hectares in year 2010, which has lost about 6.7% or some 0.16 million ha over the period of 2005-2010. Overall, Pahang has lost about 0.447 million ha at 16.98% of forest covers within 20 years between years 1990 and 2010 (Table 4).While Figure 10 shows the trend of changes in forest cover that have been occurred within the last 20 years. A spatial distribution of forest cover changes was observed as it was produced from the changes analysis (Fig 11). Currently, there are about 1.56 million ha of forests in Pahang are already reserved as Forest Reserves. The changes that have been occurred within the past 20 years were actually those outside the Forest Reserves or known as state land forests. It is obvious that the changes were concentrated in the east coast parts of the state, where most of the development activities happened. The State Forestry Department of Pahang is now placing efforts to minimize the deforestation and at the mean time trying to gazette more forests as reserved areas to ensure the intactness in the future.

The key drivers of deforestation were determined based on combination of the i) current forest cover, ii) changes forest cover, iii) boundary of permanent Forest Reserve and iv) national land use dataset. The study demonstrated that the key drivers of deforestation are commercial agriculture such palm oil and rubber plantation (Fig 12), mining, Infrastructure and Urban expansion within the periods of 20 years (Table 5). The

total rate of deforestation during the period of study stands to increase at high magnitude (Table 6)

Table 4: The estimated total forest cover for Pahang (1990-2010).

Year	Forest cover ('000,000 ha)				Total forest cover ('000,000 ha)
	Inland (a)	Peat Swamp (b)	Mangrove (c)	Forest Plantation (d)	(e) = a + b + c + d
1990*	2.299	0.301	0.005	0.027	2.633
1995*	2.292	0.300	0.005	0.026	2.623
2000*	2.138	0.250	0.007	0.027	2.424
2005*	2.104	0.232	0.007	0.000	2.344
2010*	1.993	0.188	0.003	0.000	2.186
2011**	NA	NA	NA	NA	2.068

*Quantified based on satellite image classification
**Based on statistic of forest cover 2011 (sources: FDPM Annual Report)

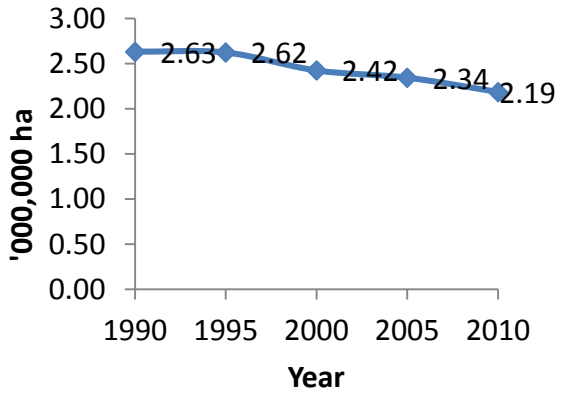


Figure 10: Trend of forest cover change
Source: Author, 2010

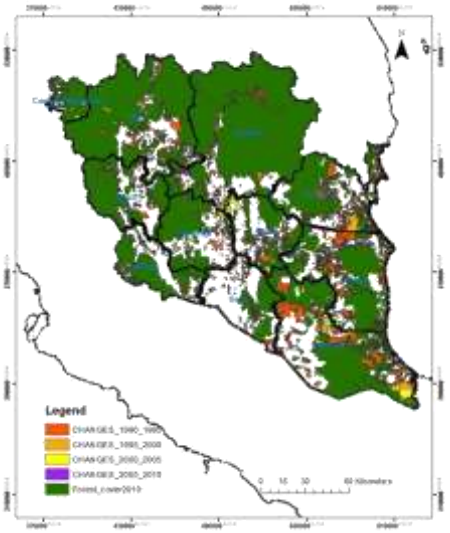


Figure 11: Spatial distribution of forest cover changes over the years 1990 – 2010.
Source: Author, 2010

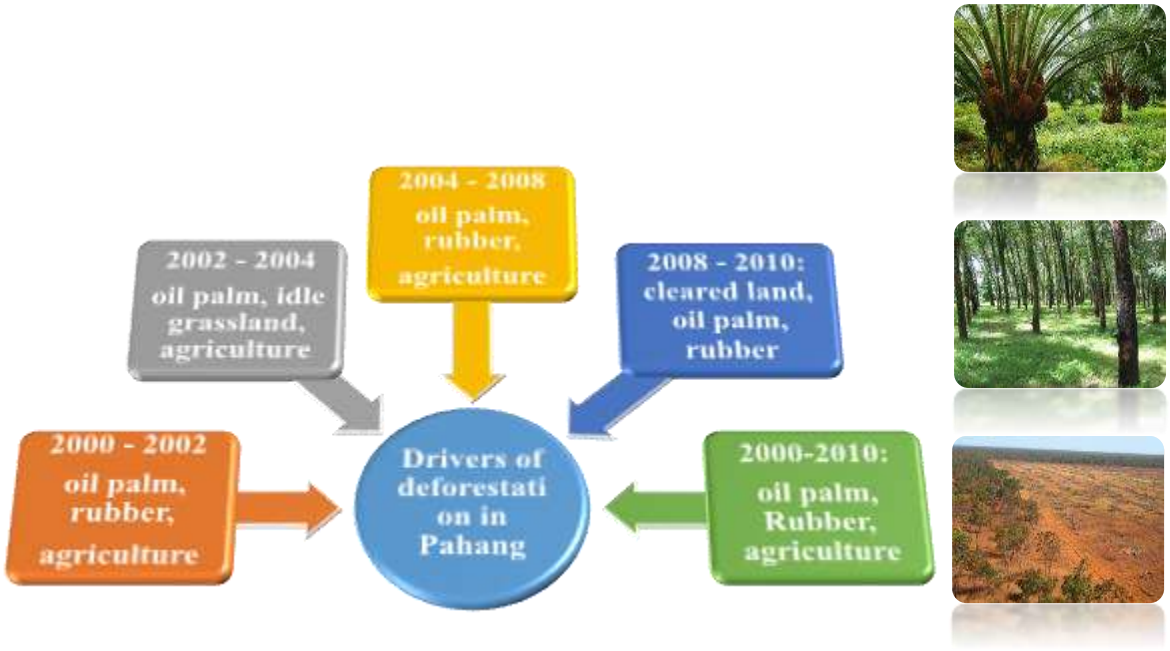


Figure 12: Key Drivers of deforestation from commercial agriculture activities
Source: Author, 2010

Table 5: Categories of Key drivers deforestation

Category	
Agriculture (commercial)	• Forest clearing for cropland, pasture and tree plantations • For both international and domestic markets • Usually large to medium scale
Agriculture (subsistence)	• For subsistence agriculture • Include both permanent subsistence and shifting cultivation
Mining	• All types of surface mining
Infrastructure	• Roads, railrods, pipelines, hydroelectric dams
Urban expansion	• Stellement expansion

Table 6: Total and rate of deforestation of the period over the study.

Intervals	Total deforestation ('000,000 ha)	Deforestation rate ('000,000 ha/yr)
1990-1995	0.010 (0.38%)	0.002
1995-2000	0.199 (7.59%)	0.040
2000-2005	0.080 (3.30%)	0.016
2005-2010	0.158 (6.74%)	0.032
Total	0.447 (16.98%)	Average = 0.020

The deforestation rates in Pahang between 1990 and 2010 indicated total deforestation occurred between 1995 and 2000 of 7.59% at a rate of 0.04 ha/year, follow by the year 2005 to 2010 with 6.74% at a rate of 0,032 ha/year. The finding is similar to the study conducted in Brazilian Amazon forest (Yosio et al., 2019) and Boneo (Brookfield and Byron, 1990). The lowest deforestation was recorded between 1990 and 1995 with 0.38% at a rate of 0.002 ha/yr while the total deforestation for the entire 30 years was 16.98% at an average rate of 0.020 ha/yr correlating the study conducted in Coasta Rica (Pontius et al., 2001). The deforestation rates in Pahang have been estimated to occurred between years 1990 and 2010 ranging from 0.002 - 0.04 million ha/yr. This finding shows that deforestation rates are significantly lower than the

others estimates for Brazil (2.60 million ha/yr), Australia (0.56 million ha/yr) and Indonesia (0.49 million ha/yr) within comparable time periods from 2000-2010 (Hansen et al., 2010; Margono et al., 2012; Grecchi, et al., 2017) These results demonstrated that Pahang is still characterized by high forest cover and slow deforestation rates. However, commercial agriculture was estimated to be the first single driver of deforestation, which accounted for about 80% of deforestation compared to other drivers. Commercial agriculture is the most important driver in Latin America (68%), while in Africa and Asia it contributes to around 35% of deforestation (Noriko et al., 2012). In Malaysia, the conversion of forested land to commercial agriculture is important as Malaysia responsible for almost half of the global dominant producer of palm oil and rubber on the world market today. Expansions of commercial agriculture on lands that have been logged or burned are typical. This expansion mostly occurred in the state land and not inside the Forest Reserve. The economic growth of the country is highly depending on the total export earned from commercial agriculture products. Others drivers include development (mostly settlement) activities, infrastructure and mining industries. The conflict of interests between land developments and forest conservations is the major issue faced by the developing countries, including Malaysia. Therefore, sustainable forest management (SFM) that is currently being practiced by the government is capable to balance the production and conservation.

CONCLUSION

The integration of multi-temporal datasets from Landsat-TM and SPOT-5 satellite images with landuse maps was capable in identifying direct drivers of deforestation. This study indicated that the drivers of deforestation are often linked to proximate or underlying drivers, as commercial agricultural such as palm oil plantation and rubber plantation was found to be the main proximate drivers for the deforestation in Pahang. The drivers of deforestation were found to spread across various locations in Pahang area with each area indicating changes in land cover. The results agree with previous work relating to monitoring deforestation using multi-temporal high resolution Landsat TM, SPOT-5 images and maps. The spatial resolution of the sensors plays an important role in indentifying various key drivers of deforestation. Future work will be to apply higher spatial resolution data and more detailed changes analysis should be carried out to define the drivers accurately.

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