DEFORESTATION ANALYSIS IN SELANGOR, MALAYSIA BETWEEN 1989 AND 2011

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AISYAH A, SHAHRUL AB, ZULFAHMIE MZM, SHARIFAH MASTURA SA, MOKHTAR J. 2015. Deforestation analysis in Selangor, Malaysia between 1989 and 2011. This study was conducted to map forest cover and detect forest change in Selangor using two types of the best satellite imageries available, namely, Landsat 4 TM and SPOT 5 representing the years 1989 and 2011 respectively. Both imageries had been georeferenced and geometrically corrected using ERDAS Imagine version 9.1. Supervised classification was performed to distinguish three types of forest cover, namely, forest land, peat swamp and mangrove. The results showed that forest land and peat swamp decreased 2.5% (4317 ha) and 12.7% (12,313 ha) respectively while the mangrove area increased 0.68% (210 ha) in 2011 compared with 1989. Total area for these three types of forest decreased by only 5.47% during this period, i.e. from 300,271 ha in 1989 to 283,850 ha in 2011. Expansion of mangrove in Selangor could be related to conservation practices in order to protect the mangrove ecosystem and reducing coastal erosion. Decreasing forest land and peat swamp cover could be related to agriculture intensification, development of new townships and expansion of infrastructure in Selangor. These results could be used to further investigate the greenhouse gas contribution and carbon stock associated with deforestation in Selangor.

Keywords: Landuse and land cover change, digital elevation model (DEM)

INTRODUCTION

Global climate change is associated with deforestation. Deforestation in the tropics is one of the biggest contributors to CO_2 emissions. It accounts for up to 20–25% of global CO_2 (Penman 2003). The rate of deforestation shows signs of decreasing for several countries but is still alarmingly high in others (FAO 2010). Global annual net loss of forest between 2000 and 2010 was 5.2 mil ha year^{-1} compared with 15.4 mil ha year^{-1} between 1981 and 1990. The loss was 8.3 mil ha year^{-1} between 1990 and 2000. Net loss is calculated by analysing the current status and recent trends for more than 90 variables and various sorts of woodlands in 233 nations and zones for four focuses of time, namely, 1990, 2000, 2005 and 2010.

Monitoring of deforestation has evolved from using conventional bookkeeping of forest area to remotely-sensed technology. Satellite imagery is now widely used in forest assessment and monitoring deforestation. It is convenient due to inaccessibility of many areas and impracticability of aircraft-based survey methods (Tucker & Townshend 2000).

Deforestation in Malaysia has been a much discussed issue since the 1970s. In those years, many forest lands had been cleared to make way mainly for rubber and oil palm plantations (Repetto 1988). In 1989–1990, urban expansion occurred up to 150% where most of the changes were within the tropical dipterocarp rainforest and mangrove forest. Total annual deforestation in Malaysia between the years 1990–2000 and 2000–2005 increased to 77% (FAO 2010). However, deforestation decreased to 37% between 2000–2005 and 2005–2010. About 0.65% of forest areas were lost yearly from 2000 till 2005 but between 2005 and 2010, the annual rate of loss was 0.41%.

While there are a few studies on deforestation in Borneo, there is no focused study on any state in Peninsular Malaysia, only a few small scale studies of forest types. The state of Selangor was chosen for this study because of its geographical

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position at the centre of Peninsular Malaysia and it has experienced very rapid growth in the last 20 years. Kuala Lumpur, the capital of Malaysia, was previously under Selangor state government is a central attraction for development or job opportunity. This paper highlights deforestation occurrences in Selangor in the years 1989 and 2011 and determine the development that has taken up the forest land. This paper also analyses the factors which may have been the driving factors of deforestation in Selangor.

MATERIALS AND METHODS

Study area

The area selected for study is the state of Selangor which is located in the west coast of Peninsular Malaysia (Figure 1). It experiences high but uniform annual temperature, humidity and rainfall and is much influenced by the east Asian monsoon system. Selangor has a total area of 791,084 ha and of this, 247,794 ha are forested land. The remaining 543,290 ha are non-forested area (Anonymous 2010a). In the mid-1980s, almost 90% of Selangor State lands were occupied by agricultural and forest areas (Anonymous 2001). However, in line with development, most of these areas have been converted into commercial and settlement areas. Although agriculture is still the principal landuse in Selangor, settlement areas had increased almost twice since the 1980s.

Methodology

Several stages of data processing were applied in order to achieve the objectives of this study. Geographic information system (GIS) and remote-sensing techniques were used for landuse classification and deforestation analysis. Figure 2 shows the flow chart of the research methodology. Primary data for 1989 was obtained from a mosaic of two Landsat 4 TM images. These Landsat images were downloaded from US Geological Survey website. Data for 2011 was obtained from a mosaic of seven SPOT 5 imageries. The imagery details are shown in Table 1. Ancillary data consisted of topographic maps, ground control points and contour data.

Landuse and land cover classification

Geometric and radiometric corrections were applied as a pre-requirement of supervised classification. All images were georeferenced to rectified skewed orthomorphic (RSO) projection and in Kertau datum. The 1989 TM image was geometrically corrected to the 2010 SPOT 5 image. The 2010 image was selected as the reference because of its higher resolution. Due to the different types of sensor used, these corrections were important for temporal analysis to reduce the effects of misregistration. Radiometric correction was done automatically for haze and noise reduction. Radiometric correction also included conversion of digital number (DN) to reflectance which was modelled and explained below. Corrections were made for SPOT and Landsat images. For SPOT 5, the following equation was used to convert digital number into reflectance value:

$$\rho = \frac{D \pi d^2}{G \sin(\theta_{se}) E_s}$$

where ρ = planetary reflectance, D = digital number, d = corrective factor to take into account the sun–earth variation distance according to the day of the image acquisition, d = 1 – 0.01674 × cos (0.9856 × (JD – 4)), JD = Julian day, G = sensor absolute calibration gain, θ_{se} = sun elevation and the last E_s = solar radiation in the appropriate wavelength.

For Landsat image, the first step was to convert the DNs to radiance using the following formula (Markham & Barker 1986):

$$L_\lambda = ((L_{max} - L_{min}) / 255) \times (DN + L_{min})$$

where L_λ = spectral radiance, L_{min} = minimum spectral radiance range (high gain), L_{max} = maximum spectral radiance range (high gain) and DN = digital number of the considered pixel. Hereupon, the apparent radiance values were converted into reflectance by the following formula (Moreira 2001):

$$\rho = \frac{\pi L_\lambda d^2}{GE_{sun} \cos(\theta_{sz})}$$

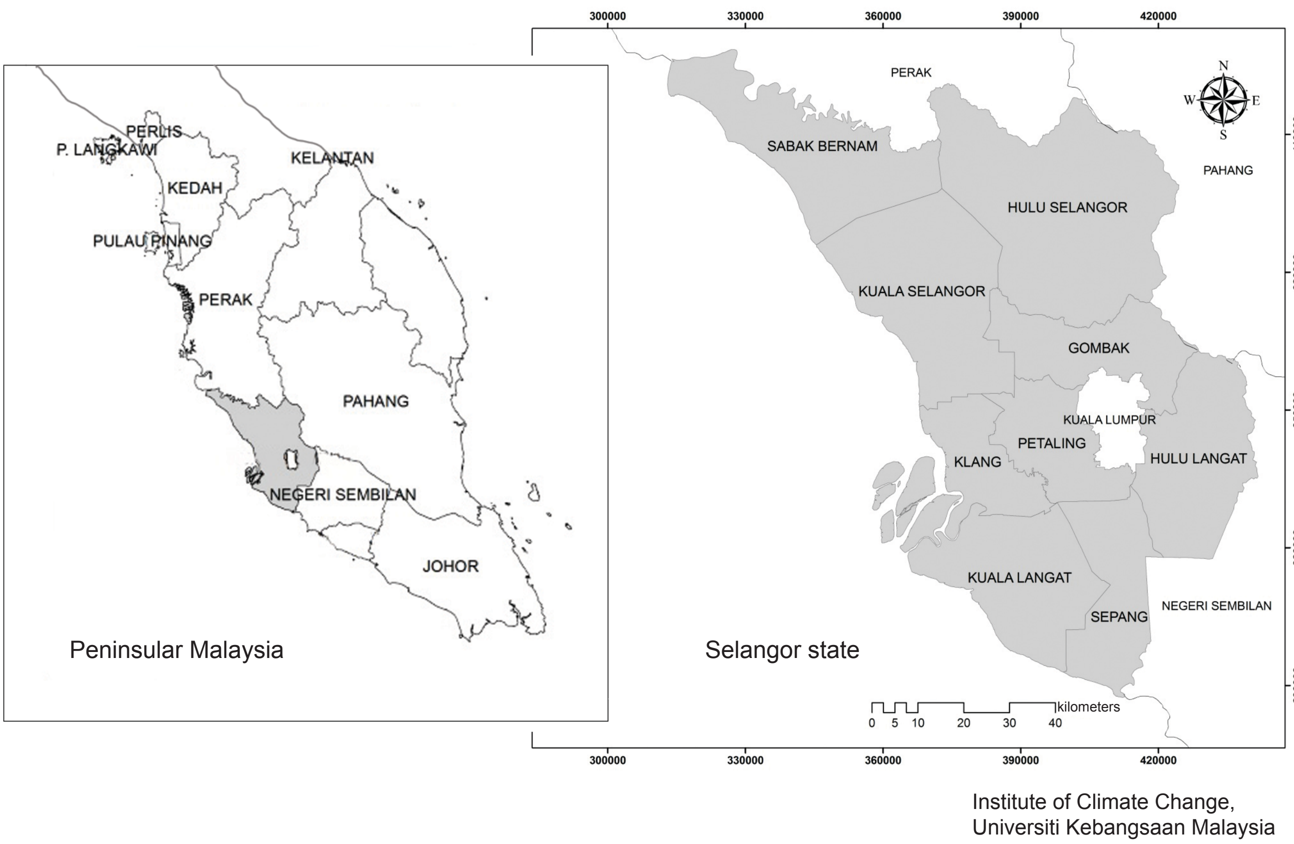

Figure 1 Selangor state map

where E_{sun} = mean solar exoatmospheric irradiance in mW cm^{-2} μm^{-1}, θ_{sz} = sun zenith angle in radians (different as above because of using cos in equation). All related parameters were obtained from metadata of the images.

Supervised classification method chosen was maximum likelihood. It was performed to classify the images to the landuse and land cover types. The earlier satellite Landsat TM data of 1989 were used as baseline data. Data from 2011 were used to capture changes from 1989. Classifications were divided into six main categories according to guidelines by the International Panel on Climate Change (Penman et al. 2003), i.e. forest land, cropland, grassland, wetlands, settlements and others. In this study, forest land was divided further to forest land, mangroves and peat swamp.

Secondary data was used as reference data to help classify the image accurately. Data used were topographic and agricultural landuse maps from the Department of Survey and Mapping Malaysia (Anonymous 1984–2001) and the Department of Agriculture, Malaysia (DOA 2008). Control points from the field data collected were used as reference points in the image geometric correction process and validation of the final classification. Total hectares and spatial maps were obtained from the forest land, mangroves and peat swamps classification.

RESULTS AND DISCUSSION

Forest land, mangrove and peat swamp have different characteristics with regard to altitude, soil conditions water regime as well as standing tree. Figures 3 and 4 show the landuse map of Selangor for the years 1989 and 2011 respectively.

Digital elevation model

Digital elevation model (DEM) data contain elevation of the terrain over a specified area which has fixed interval values between each of the grid points. A DEM for the study site was

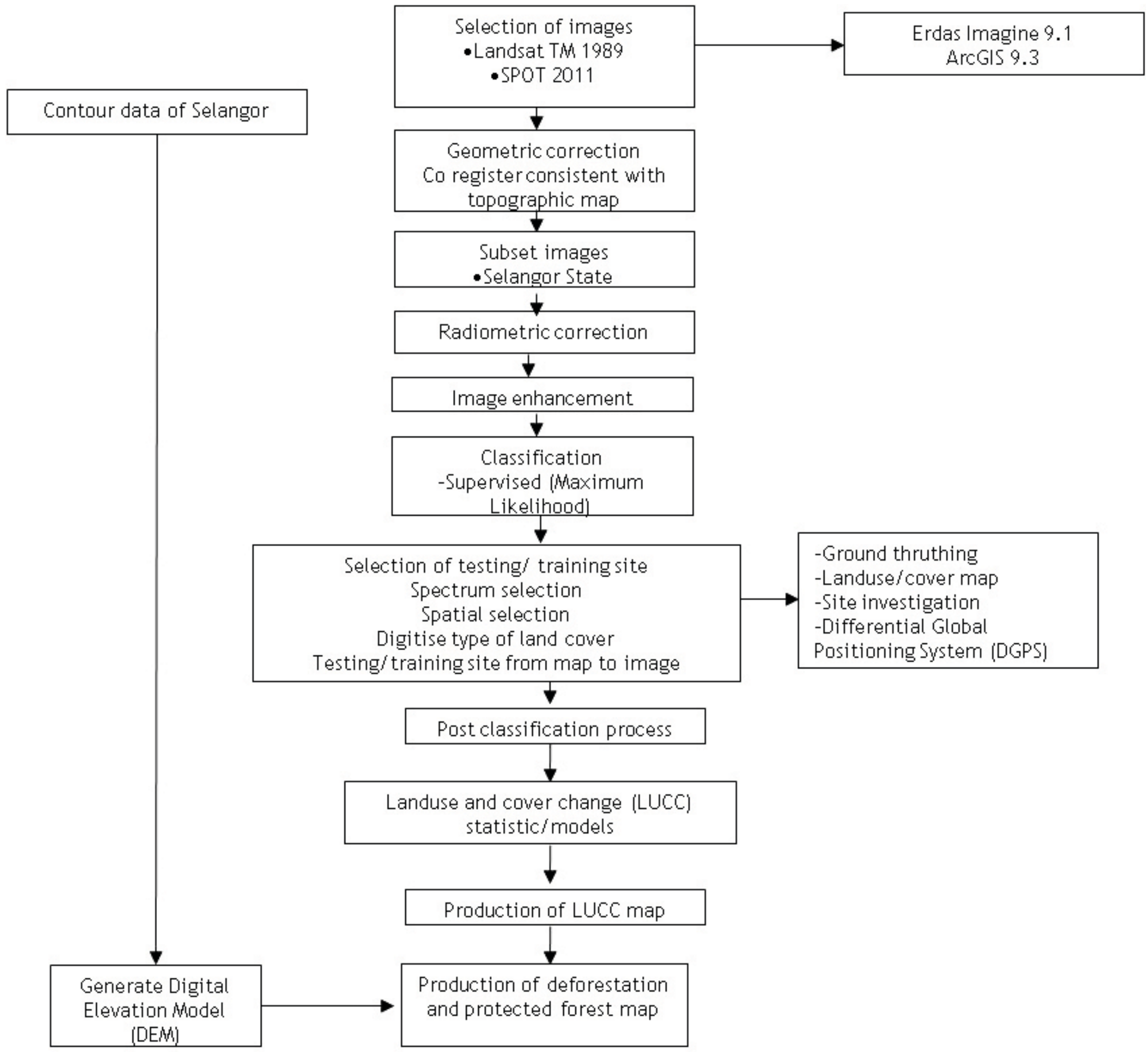

Figure 2 Methodology of research

Table 1 Details of the imageries used

Satellite/sensor	Acquisition date	Spatial resolution	Path/row
Landsat4-TM	15 June 1989	30 m	127/057
	15 June 1989		127/058
Spot 5	19 August 2011	2.5 m	268/343
	27 April 2011		269/343
	11 April 2011		269/344
	3 May 2010		270/343
	3 May 2010		270/344
	14 February 2010		270/345
	12 Mar 2007		268/342

generated from contour data of 20 m using Topo to Raster tool in ArcGis. To relate where the deforestation occurred the most, DEM data were overlaid with deforestation layer.

Figure 5 shows the deforested area consisting of changes that occurred to forest land, mangrove and peat swamps. The differences in deforested area are tabulated in Table 2. The total declining area of these three types of forest was only 5.47% for the period of 22 years. The amount appears to be small because Selangor has a large area of forest. Both forest land and peat swamp experienced reduction in area during the period of 22 years (1989–2011). Forest land decreased 4317 ha (2.50%) from 172,280 ha in 1989 to 167,963 ha 2011 while peat swamp and mangrove forests decreased by 12,313 ha (12.7%) and 210 ha (0.68%) respectively during the same period.

Distribution of Selangor protected forest is shown in Figure 6 overlaying DEM and deforested areas identified in this analysis. From the spatial distribution, it could be seen that most of the changes were concentrated at the centre of Selangor where the surface height was between 0 and 71 m. This area is still considered lowland and is affected by the urban expansion of Kuala Lumpur city and its surrounding areas. There is less deforested areas on higher lands as most of the forest in high land is under permanent forest reseve which is protected by the Forestry Act 1984.

Figures 7, 8 and 9 are maps of forest land, mangrove and peat swamps that had been converted to other classes. From the figures, we can see that forest is being converted mostly to cropland. These forests are mostly cleared to give way to oil palm plantation. The high economic value of oil palm has attracted many companies to open up new plantation areas in Selangor. The introduction and expansion of this plantation contribute to decline in biodiversity and increase in carbon emissions in this region (Koh et al. 2011). Other than an oil palm plantation, mixed agriculture also replaced forests in Selangor. For example in the peat swamp forest reserve

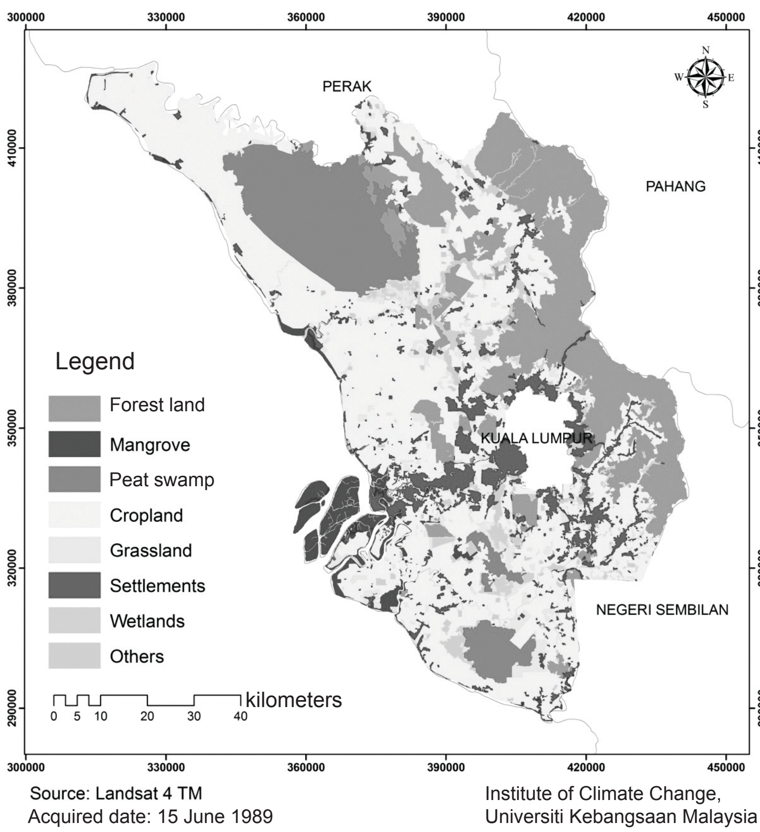

Figure 3 Landuse map of Selangor for 1989

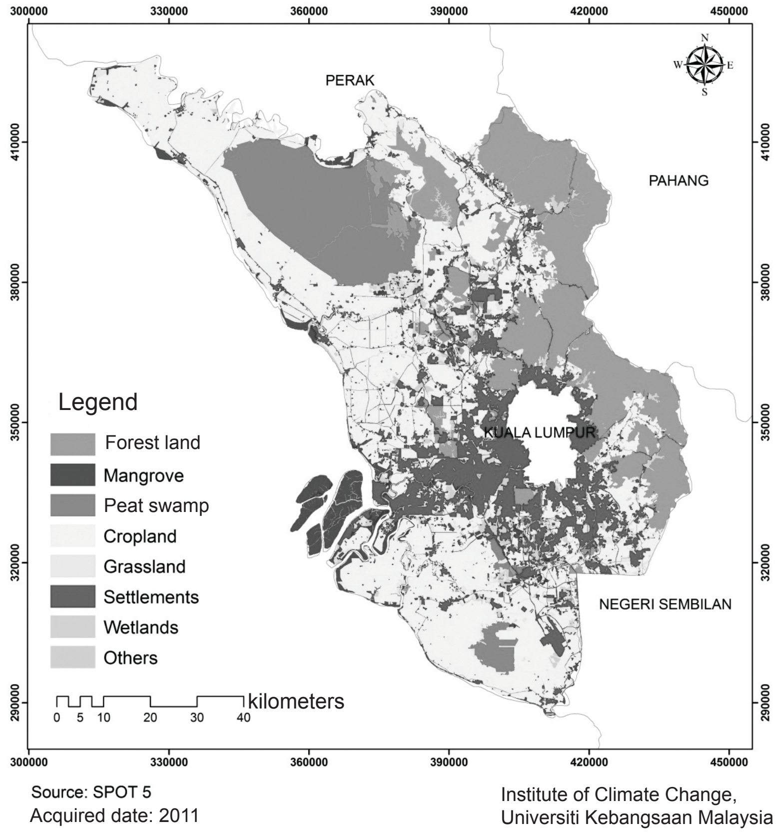

Figure 4 Landuse map of Selangor for 2011

Table 2 Landuse and land cover change for forest of Selangor in 1989 and 2011

Landuse	1989	2011	Difference	
	Area (ha)	Area (ha)	Area (ha)	%
Forest	172,280	167,963	-4,317	-2.50
Mangroves	30,734	30,944	210	0.68
Peat Swamp	97,257	84,943	-12,313	-12.7
Total	300,271	283,850	-16,420	-5.47

in Kuala Langat, oil palm and short-term crops had been widely planted and had encroached forest reserves. Peat fires occurred periodically in north Selangor and new crops took over in the burnt areas. Between 1995 and 2001, 750 ha of peat lands in Malaysia were destroyed by fire (Anonymous 2010b).

Forest land and mangrove areas were also converted to residential areas in order to accommodate the growing population due to economic development. Selangor has become attractive for residential development because of the expensive real estate market in Kuala Lumpur. Figure 10 shows the forest and mangrove areas that have been converted into large township areas. Forest and mangrove areas will continue to diminish as result of degazettement or removal from legal protection of the forest reserve by the state government (Norhayati et al. 2009).

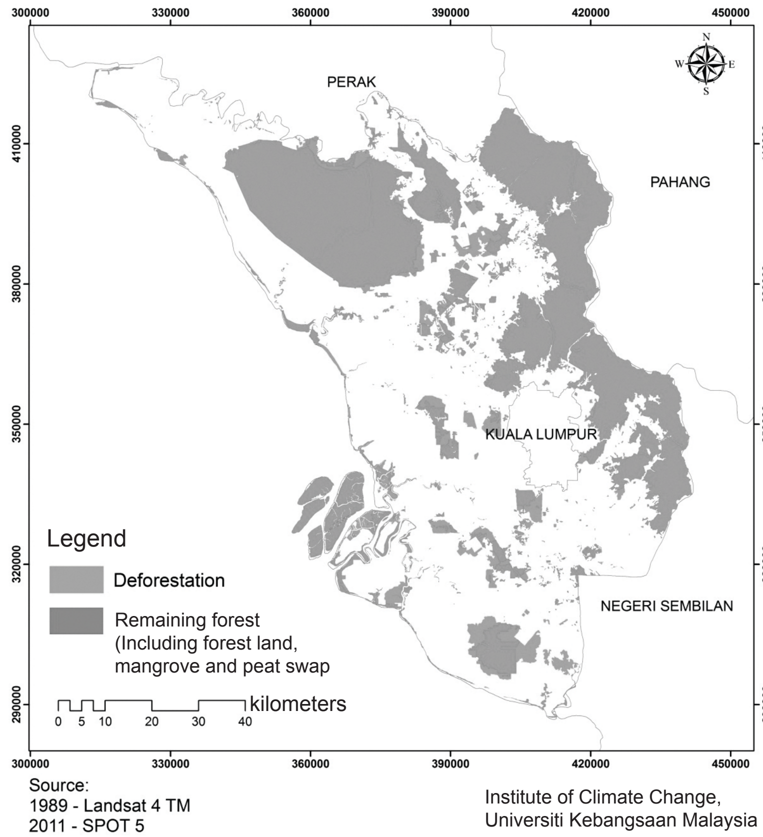

Figure 5 Deforestation map of Selangor (1989–2011)

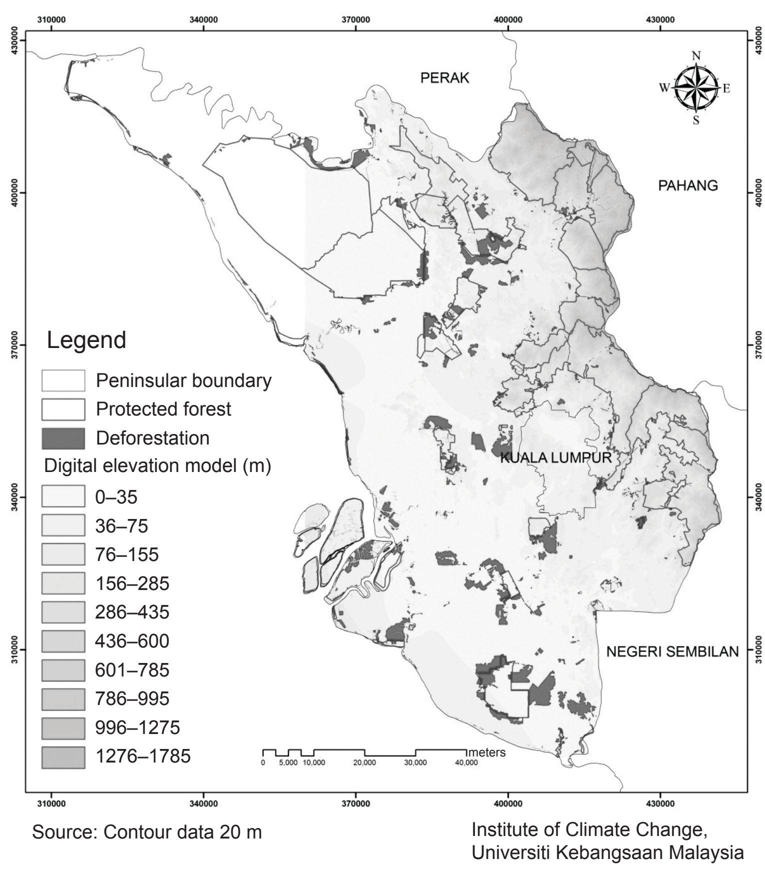

Figure 6 Deforestation and protected forests in Selangor

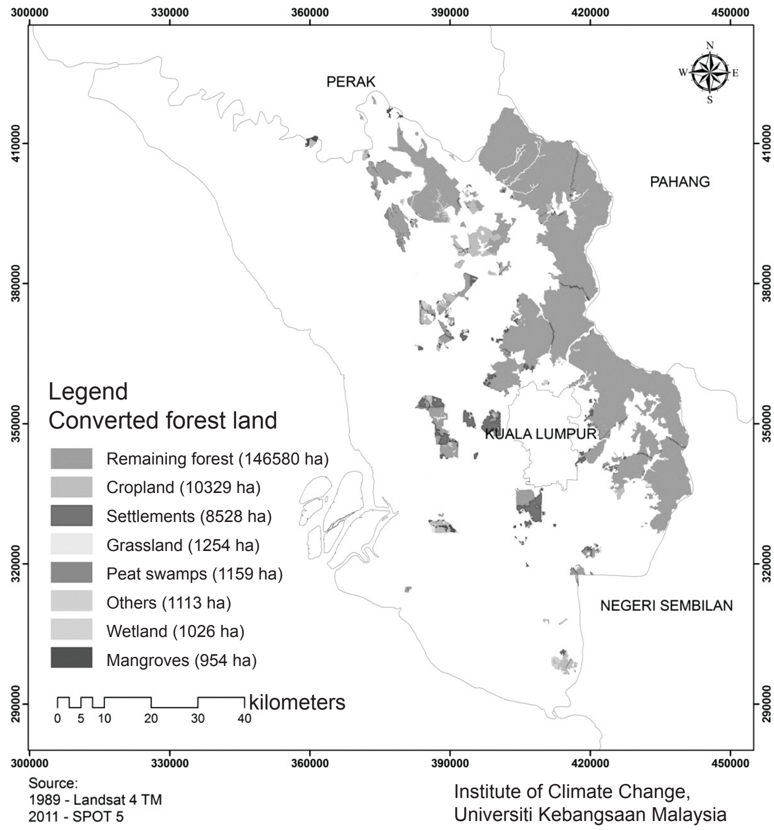

Figure 7 Conversion of forest land to other classes

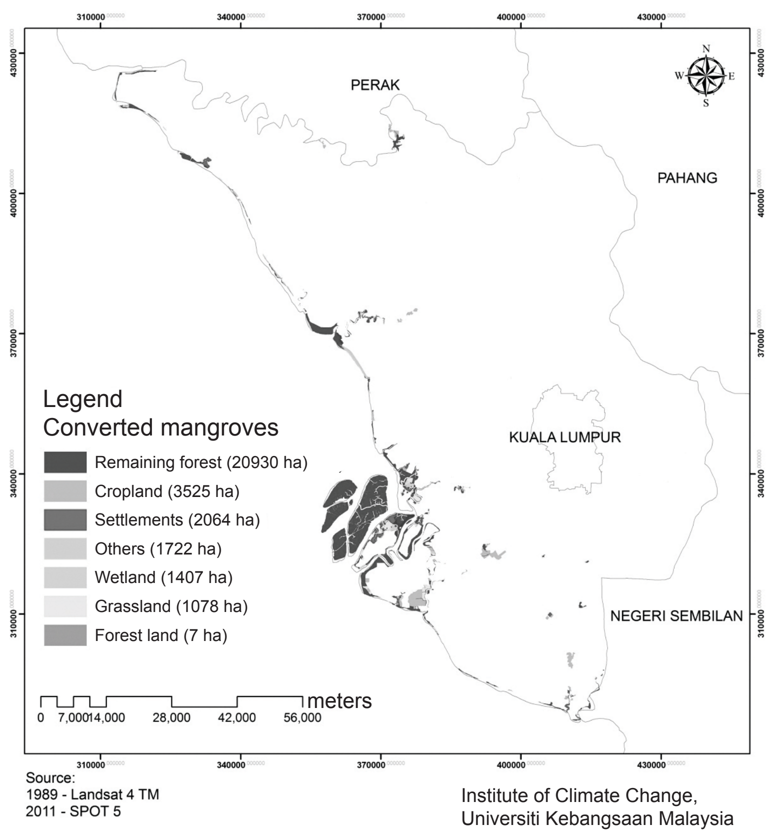

Figure 8 Conversion of mangrove to other classes

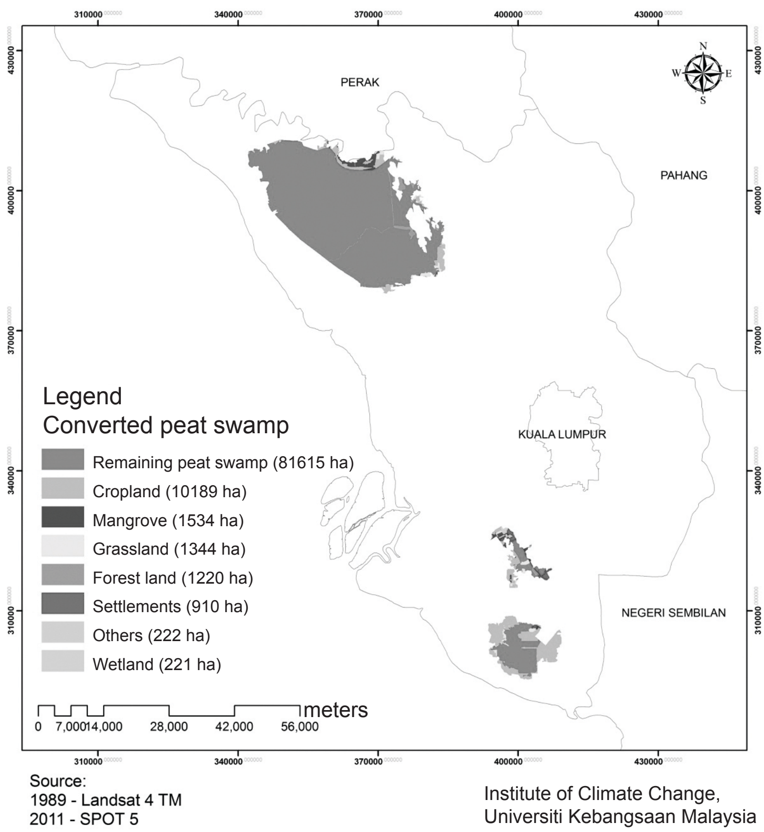

Figure 9 Conversion of peat swamps to other classes

Loss of mangrove forest is also associated with coastal erosion and logging for wood products. Despite that, the Malaysian government and corporate companies have launched several campaigns in preserving forest land and mangrove forest, including the 'Planting of 26 Million Trees' in 2010. Although awareness in issues arising from deforestation has increased, development in forest land and mangrove forest has not stopped. However, the government should probably be more cautious and more strategic planning must be in place before any project is carried out. Future policies on protected forest ought to be tightened so that the forest can continue to sustain our carbon storage on the ground and below ground.

CONCLUSIONS

The drawback of this study was the imageries used. The same type of imageries will give more accurate output. However, this project required information on landuse changes in 20 years. Therefore, Landsat 4 and SPOT 5 were chosen as they had the best and most relevant spatial resolution to cover the whole Selangor during this period.

This study showed that deforestation in Selangor was mainly caused by agriculture and urban expansion. These factors are unavoidable as population increases and demand for new housing areas continues to increase. Continuous monitoring of landuse and land cover changes using satellite imageries should be encouraged in Selangor and elsewhere in Malaysia. Results of this study could be used by decision-makers to plan for forest reserves in the future. In addition, data from this study can be used to estimate carbon stock and carbon dioxide emission in Selangor. Issues such as illegal encroachment of agricultural activities, peat fires, illegal logging and measures to mitigate deforestation can also be planned.

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No	New Township/Development
1	Tmn Bunga Raya,Bukit Beruntung
2	Desa Melor Serendah, Serendah
3	Country Homes, Rawang
4	Rawang Perdana 2, Rawang
5	Kota Puteri 5, Kuala Selangor
6	Bandar Saujana Utama, Sg Buloh
7	Subang Bestari & Subang 2
8	Kota Damansara
9	Bandar Nusa Rhu, Shah Alam
10	SHNG Villas, Cheras
11	Seksyen 2, Shah Alam
12	Seksyen U11, Shah Alam
13	Sunway & Twinners Quarry
14	Bandar Baru Sultan Sulaiman, Klang
15	Taman Seri Sementa & Taman Klang Perdana
16	Pulau Indah, Klang
17	Tmn Teluk Gadung Indah, Klang
18	Bandar Saujana Putra, Puchong
19	Dengkil
20	Taman Saujana Puchong
21	16 Sierra
22	Bandar Putra Permai, Seri Kembangan
23	IOI Resort
24	Bandar Seri Ehsan,Banting
25	Genting Sayern Paper Mill, Banting
26	Taman Segar Perdana, Cheras
27	Taman Saga, Cheras
28	Bukit Antarabangsa, Ulu Klang
29	Ukay Perdana
30	Selayang Baru, Gombak
31	UiTM Puncak Alam
32	Teluk Kapas Landfill, Klang

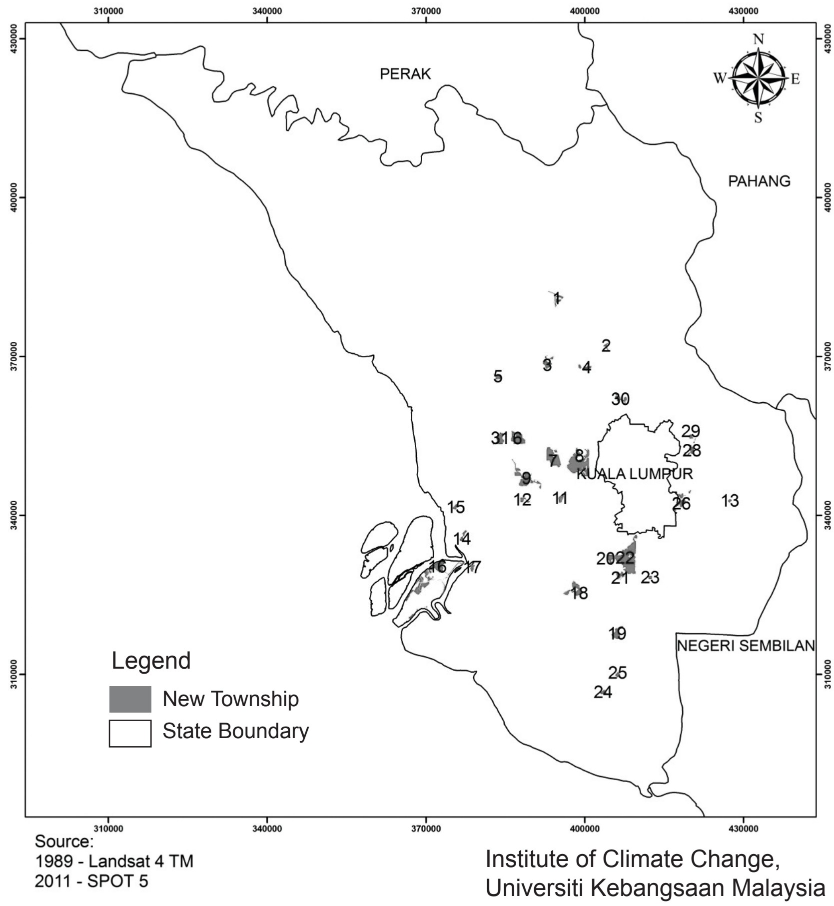

Figure 10 New townships over deforested areas

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