Jurnal Teknologi

Full paper

Assessment of Forest Encroachment Using Remote Sensing Technique. Case Study: Mentigi Forest Reserve, Cameron Highlands

Mohd Hayyi Mat Zin, Baharin Ahmad*

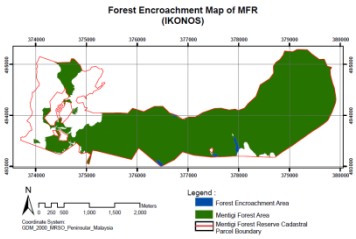
Department of Geoinformation, Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

*Corresponding author: baharinahmad@utm.my

Article history

Received :6 February 2014
Received in revised form :
21 December 2014
Accepted :26 February 2015

Graphical abstract



Abstract

Agriculture is one of the biggest and profitable activities in Cameron Highlands, Malaysia. High quality plantation products such as tea, vegetable, fruits and flower have high demand in Malaysia. These profitable activities however have caused illegal agriculture and farming. Farmers tend to extent their farm by encroaching government lands and take advantage on any open space for illegal farming. These encroachment activities have affected forest reserve area including Mentigi Forest Reserve (MFR). This study is to identify and evaluate the encroachment activities within MFR area using multiple remote sensing datasets (SPOT 5 and IKONOS). Cadastral parcel map was used to delineate the MFR area and also provide the actual size of MFR area. Hybrid classification method was used on remote sensing image to classify the land-cover in the study area. Ground truth data from field observation were used to assess the accuracy of the classification. Results of this study showed the technique used was able to identify encroachment activities such as agriculture and development. The total encroachment area in MFR was about 2.8 ha in 2001 and has increased to about 7.3 ha in 2010. These encroachment areas represent 0.39% and 1.46% respectively. This area might be small but it may affect the forest ecosystem which can lead to hazardous natural disaster if not well monitored and managed.

Keywords: Remote sensing; forest encroachment, forest monitoring, hybrid classification, cadastral parcel boundary

Abstrak

Pertanian adalah satu dari aktiviti paling besar dan menguntungkan di Cameron Highlands, Malaysia. Keluaran pertanian berkualiti tinggi seperti teh, sayuran, buah-buahan dan bunga mempunyai permintaan tinggi di Malaysia. Aktiviti yang menguntungkan ini bagaimanapun telah menyebabkan berlakunya pertanian dan perladangan haram. Petani kerap membesarkan lading mereka dengan menceroboh tanah kerajaan dan mengambil peluang terhadap sebarang tanah lapang untuk petanian haram. Aktiviti pencerobohan begini telah memberi kesan terhadap kawasan hutan simpan termasuk Hutan Simpan Mentigi (HSM). Kajian ini bertujuan menenal pasti dan menilai aktiviti pencerobohan di dalam HSM menggunakan pelbagai data Remote Sensing (SPOT 5 dan IKONOS). Pelan lot kadaster digunakan untuk menentukan persempadanan kawasan Hutan Simpan Mentigi dan juga menentukan saiz sebenar keluasan tanah HSM. Kaedah Klasifikasi Hibrid telah digunakan terhadap imej Remote Sensing untuk mengklasifikasi litupan tanah (*land-cover*) di kawasan kajian. Data lapangan (*ground truth*) dari cerapan lapangan telah digunakan bagi menilai ketepatan klasifikasi. Hasil kajian menunjukkan teknik yang digunakan mampu mengenal pasti aktiviti pencerobohan seperti pertanian dan pembangunan. Jumlah keluasan pencerobohan di HSM adalah dalam lingkungan 2.8 hektar pada 2001 dan telah bertambah kepada dalam linkungan 7.3 hektar pada 2010. Keluasan pencerobohan ini mewakili 0.39% dan 1.46% Keluasan ini mungkin kecil tetapi ia mungkin memberi kesan kepada ekosistem hutan yang munkin menyebabkan bahaya bencana semulajadi yang jika tidak diawasi dan diurus dengan baik.

Kata kunci: Remote sensing; pencerobohan hutan, pengawasan hutan, klasifikasi hybrid, persempadanan lot kadaster

1.0 INTRODUCTION

Ever since Cameron Highlands was opened, agriculture activities in this area have rapidly increased. Highland climate and tropical rain forests provides suitable environment and temperature for agriculture activities. High quality vegetable, fruit and flower from this area have high demand and sought after by population

of Malaysia. Since then agriculture activities have been one of economic resource in Cameron Highlands besides tourism.

The richness of this highlands area however has lead to forest encroachment activities in recent years as newspapers have reported about forest opening and illegal agriculture activities in Cameron Highlands [7]. This issue has been linked to several natural disaster occurrences which had consumed lives and caused lot of damages.

Continuous forest monitoring is necessary in order to manage and control this problem. Monitoring from above might be the ideal way for the responsible agencies to counter this problem. In this decade, remote sensing technology is well known as a tool for land use and land cover mapping [4], [6], [8]. Various remote sensing techniques have been developed that can be used for forest monitoring purposes on activities such as forest encroachment [6]. The ability of remote sensing techniques to classified and map land cover make it suitable for forest monitoring. Remote sensing data have multiple scales ranging from a few metres to several kilometres scale could help researcher to study local and manage global level of forest resource. The availability of multi-temporal data acquisition that allow new data to be acquired daily, monthly or annually and previous date data in the archive give advantage in monitoring at regular basis. Multiple remote sensing data scales with synoptic sensor coverage can give information in inaccessible places, thus help to detect any illegal forest activity in an area. Although remote sensing only provides complimentary information, it is still quite effective tools in assessing and monitoring forest [7].

This study was aimed at identifying and calculating the area of encroachment that happened within the MFR area. An assumption has been made based on *Dasar Perhutanan Negara 1977* (Malaysia, 1966), to identify the forest encroachment. Using the assumption that any activities occurred within the MFR area except if the activities were undertaken by the government, then it was considered as encroachment. This encroachment area was assessed using remote sensing techniques. The procedures and methods used in this study can be applied in other related study in the future.

2.0 STUDY AREA

The study area is Mentigi Forest Reserve (MFR), located in Cameroon Highlands, Pahang, Malaysia. Cameron Highlands is located in the main highland range of Malaysia about 150 km North of Kuala Lumpur. The physical topography of the Cameron Highlands is rough and hilly. Local relief ranges from 800 to 2200 m. Some areas are mountainous particularly along the western parts. The eastern part of the area is dominated by hillands. There are flat valleys, which run from North to South, mixed with small hills. Major small town settlements are located here like the town of Tanah Rata, Ringlet, Tringkap and Kuala Terla. Valleys can also be found along main rivers such as Bertam River in the south at Ringlet and the Telom River in the north at Kuala Terla that both drain from west to east. Native dense rain forest still covers most of the landscapes particularly in the mountainous and hilly areas surrounding the agriculture areas. Besides the primary forest, there are plantations with chosen species of forest trees. This area is gazetted as forest reserve. The study area was selected based on the existence of suspected illegal forest clearing activities for farming. MFR area is surrounded by human activities area such as development and agriculture areas. This forest serves as water catchment area and also accommodates a hydroelectric tunnel that used to tunnel water into the nearby hydroelectric dam. Any encroachment activities within this reserved forest can cause disaster to this tunnel facility and residential area surrounding the forest reserve area.

3.0 DATA AND METHOD

Two multi-spectral remote sensing satellite images (IKONOS and SPOT5 images) acquired on different dates were used in this study. IKONOS image which was acquired in March 2001. This image has 4 multispectral bands and has 1 metre spatial resolution pixels. Second image is SPOT5 image which was acquired on February 2010. This image has 5 metres spatial resolution pixels and 4 spectral bands.

These two images were first geo-referenced in order to reduce geometric error. Since the study area was mostly covered by forest, the geo-reference process was done on the full scene image. Image to image registration was done between these images in order to make it fit to each other. The clouds in the satellite images were masked and these masks were combined and applied in both images to make sure they are identical. The MFR area was extracted from these two images with reference to boundary of cadastral parcel after the classification process. Figure 1 show the work flow for this study.

The information about land cover was then extracted using hybrid classification method. The classification technique of ISODATA clustering algorithm from unsupervised classification was used to cluster the spectra and this cluster was used as training sample for supervised algorithm [2]; [5]. Maximum Likelihood algorithm was used for supervised classification part for its probability based decision rule to assign each pixel based on sample data [1]. This algorithm commonly use supervised classification algorithm. This classification process was done to the whole images which include MFR area and its surroundings. It is to ensure more land cover sample was used in classification process and to increase the accuracy of the classification. The accuracy of this classification was assessed using confusion matrix method. The ground truth information was collected in the surrounding study area for this purpose. The overall accuracy for classification of IKONOS image is 84.97% and kappa coefficient is 0.8823. While overall accuracy for SPOT image is 88.79% and kappa accuracy is 0.845. The results show there is high correlation between the classified image and ground truth information. The forest land cover from the classification was converted into vector format for easier data manipulation and analysis in further process. The MFR areas for both images were then extracted with reference to vector cadastral parcel boundary that delineates the MFR area. Figure 2 show the MFR area of classification result.

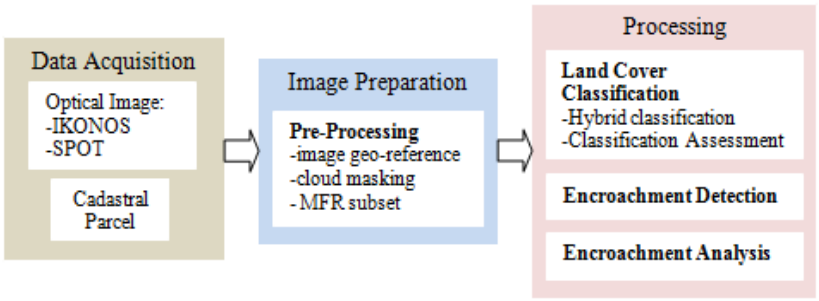
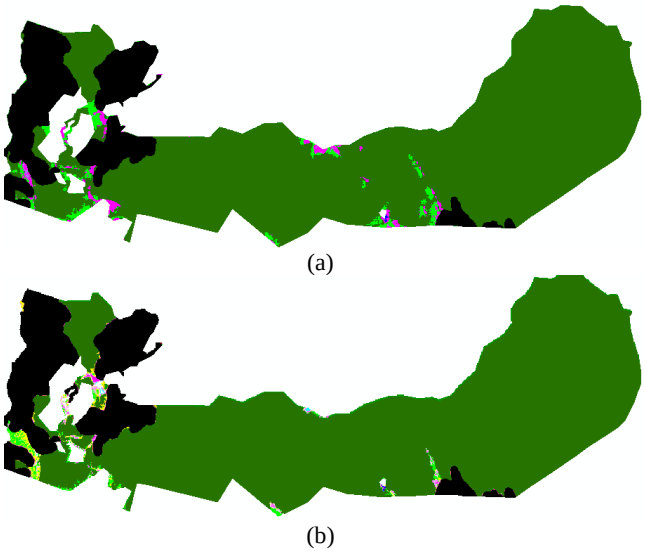


Figure 1 Workflow of the study



(a)

(b)

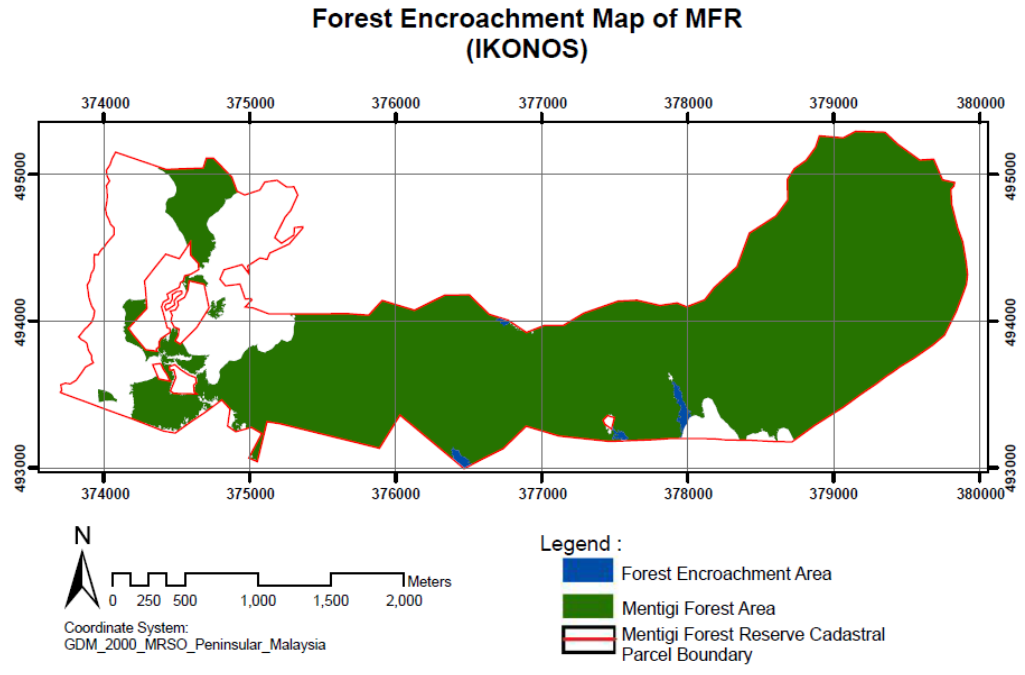
Figure 2 Classification result for SPOT 5 (a) and IKONOS (b) image. Dark green represents forest area, light green and yellow represent agriculture area, and magenta represents urban area

From classification result, several land covers within MFR area were identified. These land covers include road connection; government activities areas such as transmission line and dam; and encroachment areas. Thus, to identify encroachment area, the vector forest covers were carefully checked with classification result. By comparing with classification result, the causes of encroachment were also identified. Result from forest encroachment detection was then analysed in term of size and extent between year 2001 and 2010, and also the causes of the encroachment.

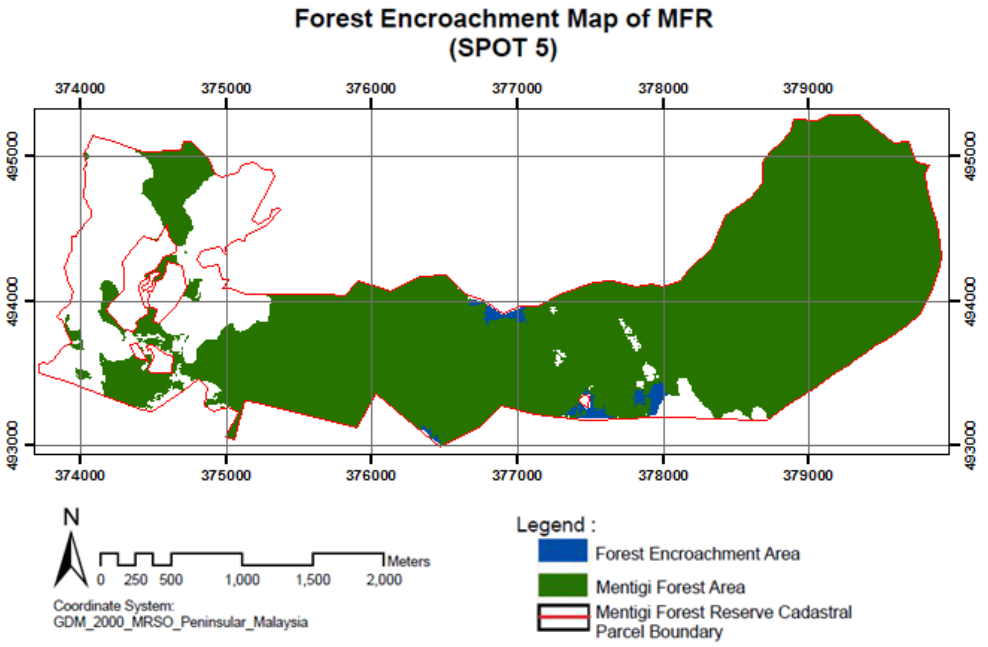
4.0 RESULT AND DISCUSSION

It is assumed that there is encroachment activity if the area is classified as agriculture or development area except when the development is undertaken by the government. Examples of government development activities are road, transmission line and dam. Therefore, from classification result (Figure 2), it indicates encroachment activities have taken place within MFR area.

The classified forest cover, agriculture cover and development area were overlaid with cadastral parcel of the MFR (vector map) to produce forest encroachment map (Figures 3a and 3b). These forest encroachment maps from both images were masked from cloud covers.



(a)



(b)

Figure 3 Forest encroachment map extracted from IKONOS image (a) and SPOT 5 image (b)

Table 1 Total encroachment area of Mentigi Forest Reserve from cadastral parcel, IKONOS and SPOT after taking into consideration of cloud, detected utility and uncovered areas

Data	MFR Area (ha)	Cloud mask area (ha)	Detected Utility + Uncovered areas (ha)	Forested area of MFR (ha)	Encroachment area (ha)
Cadastral Parcel	706.46	115.19	-	591.27	-
IKONOS	706.46	115.19	18.47	570.02	2.78
SPOT	706.46	115.19	18.87	565.12	7.28

Analyses of MFR area and forest encroachment have been made from the study, which presented in Table 1 and Table 2.

In Table 1, the total area (706.46ha) of reference data represents the actual gazetted forest reserve area. Since the forest has been encroached, the difference in the size of the extracted forest area is expected. The total forested area extracted from IKONOS and SPOT 5 data are slightly less (570.020ha and 565.116ha) compared to reference data (cadastral parcel boundary) area (591.269ha). This is due to utility and uncovered areas which already excluded in cadastral parcel but exist in the two images. The forest area extracted from that SPOT 5 dated in 2010 is slightly smaller than the reference data and decreased further, slightly compared to IKONOS image dated in 2001. This shows very little encroachment activity has taken place within MFR in 2001 and also during 2001-2010 period. This decreasing of MFR area indicates that forest encroachment activities did take place in MFR area. The encroachment analysis was undertaken and presented in Table 2.

According to Table 2, total encroachment area detected in IKONOS of year 2001 image is 2.7786 ha and about 7.2805 ha was detected on SPOT 5 of year 2010. This shows that between year 2001 and 2010, the forest encroachment area has increased by 4.5019 ha. Through the analysis of encroachment purpose or causes, most of the encroachment was carried out for agriculture activities (Table 2). A total of 2.5714 ha of agriculture based land cover were detected in 2001 and this area has increased to 4.9567 ha in 2010. This shows that some farmers with land share border with MFR tent to extend their farm beyond their shared boundary into MFR area.

Table 2 Encroachment area analysis of the Mentigi Forest Reserve area

No.	Description	Area (ha)
1	Total encroachment IKONOS MFR(2001)	2.78
2	Total encroachment SPOT 5 MFR (2010)	7.28
3	Area of encroachment due to agriculture (IKONOS) (2001)	2.57
4	Area of encroachment due to agriculture (SPOT 5) (2010)	4.96
5	Area of encroachment due to development (IKONOS) (2001)	0.21
6	Area of encroachment due to development (SPOT 5) (2010)	2.32

The other source of forest loss within MFR area which declared as encroachment is development. Development was actually a legal activity and usually has government authorization. From Table 2 it can be seen that encroachment due to development has increased during 2001 to 2010.

Although the encroached area within MFR area was relatively small, if not stopped this problem can be a big issue for Cameron Highland.

5.0 CONCLUSION

Based on result of this study, it can be concluded that illegal activities did happen within Mentigi Forest Reserve (MFR) area. Most of these illegal activities which also considered as encroachment were carried out for agriculture purpose. This illegal agriculture activities in Cameron Highlands area is very profitable.

Encroachment exist whenever there are accessible route that goes into MFR area. For example the existence of abandon route crossing the MFR have caused encroachment activities by the roadsides along the route.

From this study, a method for forest encroachment monitoring was constructed and it is high hope that the remote sensing methods and procedures used in this study can be used by responsible agencies to monitor and control forest encroachment problem in the future.

Acknowledgement

Special thanks to Universiti Teknologi Malaysia (UTM) and Institute of Geospatial Science & Technology (INSTEG) Faculty of Geoinformation and Real Estate, UTM Skudai for support of this study. The authors also would like to thank Ministry of Higher Education for providing grant that support the financial for this study. Last but not least, thank also to Malaysia Remote Sensing Agency (MRSA) for providing data for this study.

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