FOREST ENCROACHMENT MAPPING IN CAMERON HIGHLANDS, USING CADASTRAL PARCEL AND REMOTE SENSING DATASETS

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DEDICATION

Specially dedicated to Ayoh (Mat Zin Bin Hussain)

and Umi (Siti Rugayah Binti Yaacub),

thank you for your never ending support,

And also to the special woman, my wife Aisya Azizah Abas

that always be together,

your love is my inspirations.

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ABSTRACT

High demand of agriculture product from Cameron Highlands has caused unauthorized agriculture activities to emerge. When agricultural land is highly in demand and agriculture land becomes scarce, the government land, mostly forest areas are being encroached for this purpose. The forest encroachment which include cutting down trees on hill slopes, can cause negative impact on forested area in Cameron Highlands including Mentigi Forest Reserved (MFR) area, which also serve as water catchment area. This study is to detect and assess this encroachment especially that caused by agricultural activity in MFR area and its surrounding, using remote sensing datasets and cadastral parcel. The hybrid classification method was applied on remote sensing images to classify the land-cover types in the study area. Cadastral parcel was used as a reference for forest reserve area boundary to detect some agricultural activities inside the forest reserve area. The findings reveal that around 8.75 ha of forest encroachment was detected using SPOT 5 image of year 2010, and 2.98 ha were detected using IKONOS image of year 2001. It was found that most of the encroachments were meant for agricultural purpose. Accuracy of the extracted forest boundaries from satellite images was assessed using the Root Mean Square Errors (RMSE). The displacement value for IKONOS and SPOT 5 were 8.11 m and 12.99 m respectively. These errors were further reduced using buffer zones that was applied to reduce the error effect on encroachment detection. This method was also applied to the entire subset of satellites image to identify encroachment areas inside the forest reserve and surrounding areas. Results of this analysis show that forest encroachment occurred inside MFR area despite its relatively small size. The study has proven that the technique used is an effective method in assessing small forest encroachment area.

ABSTRAK

Permintaan tinggi terhadap produk pertanian dari Cameron Highlands menyebabkan aktiviti pertanian haram berlaku. Apabila penggunaan tanah pertanian meningkat dan menjadi terhad, tanah kerajaan yang kebanyakannya merupakan kawasan hutan dicerobohi untuk tujuan ini. Pencerobohan hutan seperti penebangan pokok di lereng bukit, boleh memberi kesan negatif kepada kawasan hutan di Cameron Highlands termasuk kawasan Hutan Simpan Mentigi (MFR), yang juga digunakan sebagai kawasan tadahan air dan empangan. Tujuan kajian ini ialah untuk mengesan dan menilai pencerobohan yang berlaku terutama yang disebabkan oleh aktiviti pertanian di kawasan MFR dan kawasan sekelilingnya dengan menggunakan data remote sensing dan lot-lot kadaster. Kaedah pengkelasan hibrid telah diaplikasikan pada imej-imej remote sensing untuk mengelaskan jenis litupan tanah dikawasan kajian. Lot-lot kadaster telah digunakan sebagai rujukan sempadan hutan simpan. Hasil kajian menunjukkan kira-kira 8.75 ha pencerobohan hutan telah dikesan menggunakan imej SPOT 5 tahun 2010 dan 2.98 ha dikesan menggunakan imej IKONOS tahun 2001. Kajian mendapati bahawa kebanyakan aktiviti pencerobohan digunakankan untuk tujuan pertanian. Ketepatan sempadan hutan untuk imej satelit telah dinilai dengan menggunakan selisih purata punca kuasa dua (RMSE) bagi anjakan IKONOS dan SPOT 5 masing-masing ialah 8.11 m dan 12.99 m. Seterunya selisih-selisih ini dikurangkan lagi dengan menggunakan zon penampan yang digunakan bagi mengurangkan kesan ralat pada pengesanan kawasan pencerobohan. Kaedah ini juga telah diaplikasikan bagi keseluruhan subset imej satelit untuk mengesan pencerobohan hutan di dalam kawasan hutan simpan dan sekitarnya. Hasil analisis menunjukkan bahawa pencerobohan hutan berlaku di dalam kawasan MFR, walaupun ia hanya melibatkan saiz yang kecil. Kajian ini juga membuktikan bahawa teknik yang digunapakai adalah kaedah yang efektif untuk menilai kawasan pencerobohan hutan yang bersaiz kecil.

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LIST OF ABBREVIATIONS

ASTER	-	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ArcGIS	-	Arc Geographic Information System software
BPA	-	Boundary Positional Accuracy
CN	-	Color Normalized
DCDB	-	Digital Cadastre Database
DEM	-	Digital Elevation Model
DSM	-	Digital Surface Model
DTM	-	Digital Terrain Model
ENVI	-	Environment for Visualizing Images
ERDAS	-	Earth Resources Data Analysis System, software
FAO	-	Food and Organization
GCP	-	Ground Control Point
GDEM	-	Global Digital Elevation Model
GDM 2000	-	Geocentric Datum of Malaysia 2000
GPS	-	Global Positioning System
HSV	-	Hue Saturation Value

IKONOS	-	No acronym, name of Spanish Earth Observation Satellites
ISODATA	-	Iterative Self-Organizing Data Analysis Techniques
JUPEM	-	Department of Survey and Mapping Malaysia
LiDAR	-	Light Detection and Ranging
METI	-	Ministry of Economy, Trade and Industry, Japan
MLC	-	Maximum Likelihood Classification
MFR	-	Mentigi Forest Reserve
MODIS	-	Moderate Resolution Imaging Spectroradiometer
MRSA	-	Malaysia Remote Sensing Agency
NASA	-	National Aeronautics and Space Administration
NDCDB	-	National Digital Cadastre Database
NOAA	-	National Oceanic and Atmospheric Administration
OFA	-	Object Fate Analysis
PC	-	Principal Components
PCC	-	Post-Classification Comparison
RADAR	-	Radio Detection and Ranging
REACH	-	Regional Environmental Awareness Cameron Highlands
RGB	-	Red, Green and Blue
RMSE	-	Root Mean Square Error
RPC	-	Rational Polynomial Coefficients
RSO	-	Rectified Skew Orthomophic

RST	-	Rotation, Scaling and Translation
SPOT 5	-	Systeme Probatoire D'Observation De La Terre 5 (France's Earth Observation Satellite)
SPRM	-	Malaysian Anti-Corruption Commission
SRTM	-	Shuttle Radar Topography Mission
TGO	-	Trimble Geomatics Office
UAV	-	Unmanned Aerial Vehicle
UTM	-	Universal Transverse Mercator
WGS84	-	World Geodetic System 1984

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Forest is one of the major natural resources that is essential for life on earth. Human populations from worldwide depend on it for their livelihood such as timber production, oxygen supply, watershed protection and many other beneficial uses. Forests also serve as habitats for millions types of floras and faunas.

According to Jian (2010), deforestation is one of the major component in modifying global environmental change and has severely influence towards the productivity of ecosystem such as the ability of removing carbon dioxide and other greenhouse gases from atmosphere. Moreover, human-induced activities such as land use change due to urbanisation and forest encroachment have imposed tremendous damage upon the ecosystem. Numbers of forest cuts have increased annually and it takes decades for the forest to restore. The question is how much environmental damage does it take for the forest to restore to its normal condition? And what will happen if the forest will never return to its original state. The well planned forest opening is important to avoid problems from deforestation. The forest encroachment is one of unplanned deforestation and a diseased to the environment if nobody prevents or controls it. Detecting encroachment area seems little bit complicated to be done. Using land use record alone will be not enough without field visit. Real time and real earth surface image from remote sensing technologies can assist to detect and monitor wide swaths of areas which have been damaged by human activities (Fuller, 2006).

Various factors from complex socio-economic pressures such as the growth of land and commodity values have led to conversion of forest for agricultural and plantations purposes. This phenomena is known as encroachment and is at vital issue. Recently, it has raise concern among public and policy makers due to huge damage of environmental resources (Fearnside, 2005; Janisch and Harmon, 2002). Consequently, the degradation of world forest area continues at an alarming high rate which is approximately 13 million hectares per year have been converted to other land use and caused immediate consequences as biodiversity loss, loss of hydrological capacity, and increased net emissions of greenhouse gases (Fearnside, 2008).

In Malaysia, the reserve forest is entrusted under the supervision of state government as stated in 'Dasar Perhutanan Negara, 1977'. According to 'Kanun Tanah Negara' a person or any party or organization can be accused to have committed encroachment of government land when they are doing one or more of the following matter without lawful authority (Malaysia, 1966):-

1. Set up building or lived on the government land or mines land
2. Clearing, ploughing, digging, opening, or planting in the part or whole of government land area
3. Cutting or removing any timber or any other woods from the land.

Forest depletion is amongst leading causes that bring serious impact towards the environment. The latest example on environmental degradation due to deforestation is the landslides that occurred on the 8th August 2011, at Sungai Ruil aboriginal settlements, Cameron Highlands, which claim the lives of seven people and destroyed many other houses. Another problem which occurs due to forest depletion is the rise in global temperature or also known as global warming. The release of carbon gases that is stored in the vegetation to the air. The absorption of carbon is also reduced. Carbon is one of the greenhouse gases. When this gas is stored in the atmosphere increased, it will trap more heat and cause the greenhouse effect. Other than that, deforestation may also cause numerous problems that can be harmful to human and also the environment.

Nowadays, forest encroachment problem have been a serious issue in Malaysia especially in one of Malaysia's tourism area, Cameron Highlands. Since the first access roads to Cameron Highlands from town of Tapah were built, the agriculture activities in this highland have rapidly increased. The low highlands temperature makes this area suitable for agriculture. Vegetable, flower, and fruit from Cameron Highlands have high demand and sought after by population of low land areas in Malaysia. Since then agriculture activities have been one of economic resource in Cameron Highlands besides tourism. The increasing of socio-economic activities has caused pressure in macro-economy sector which led to the rise in land and commodity values. Because of this, deforestation takes place especially for agricultural and residential areas.

Deforestation for development in Cameron highlands area may not seem serious since most of the residential areas or development areas are well planned by the government. However, for agriculture purpose, many farmers tried to gain more profit by extending their land size by encroaching into neighbouring government land that includes forest area. This problem might lead to unmanaged deforestation. Besides this long time effect, deforestation may also cause serious natural hazard of landslide that occurs more often in highland areas. Occurrence of landslide in Cameron Highlands would cause catastrophe, since it will have direct impact toward the residential areas, tourism areas, hotels, and developed areas. In Cameron Highlands, these places are mostly surrounded by high hills with steep slopes and some of the buildings are built on top of hills and on slopes. Landslides have occurred in Cameron Highlands numerous times, which one of them was in aboriginal village of Sg. Ruil as stated earlier.

Changes in forest boundary can be a good indicator of the encroachment or deforestation. By detecting and monitoring the changes in boundary, the assessment on forest depletion can be made. Many techniques have been used to detect and monitor the changes on forest boundary in order to study encroachment problem. Common traditional field survey on forest boundary seems helpful except it cannot cover wide area in a short period of time. Remote sensing techniques on the other hand, provide several methods for this application in lowering cost and can be done in shorter time (Raggam *et al.*, 2007). Various types and resolutions of remote sensing data make it reliable to detect forest change and also land cover change. The appropriate method in remote sensing technique can produce an accurate result in a short time.

Different applications are currently in use to collect as well analyse remote sensing data. These data's are either from ground-based, airborne, and even Earth-orbiting platforms to be used in several sectors (Franklin, 2001; Toomey and Vierling, 2005). In addition, the different sets of techniques and data obtained by remote sensing technologies have made tremendous contributions over the last three decades in identifying deforestation, result of human encroachment activities in tropical forests (Turner *et al.*, 2007; Turner and Robbins, 2008). Use of low and medium resolution of remote sensing data such as Landsat, NOAA and MODIS, provides large scale mapping of deforestation in a very short time. This resolution level however cannot successfully map the small scale deforestation which might cause by small area farming activities. The availability of high resolution remote sensing data however can be used for small scale mapping. High spatial resolution images however, also have their own limitation such as heavy cloud cover and shadow effect which might affect the accuracy of the final result. With this advance remote sensing technologies, the potential of remote sensing equipment to detect the full impact of deforestation due to human encroachment can be enhanced.

The result from the application of forest encroachment must be accurate in order to identify the encroachment area as well determine the total area (acreage). High spatial resolution for remote sensing data is suitable for this purpose. The accuracy of the result derived from this data need to be assessed, especially the accuracy on the boundary location and the size of the affected area. The boundary between different classes of land cover produced from different resolution images might be affected by mixing pixel of the multi spectra data. To make assessment, most researchers used reference data such as topology map, land use map, land cover map, or any visual digitize vector data for comparison. In this research, to achieve the high accuracy result for forest encroachment mapping, high accuracy cadastral parcel was used for aid on boundary delineation and mainly as reference data for assessment. The cadastral parcel that contains information about property boundary is produced from ground survey work, which has accuracy up to a centimetre level.

Boundary accuracy assessment is often applied to assess the object based classification result. The boundary of the object derived from this classification is assessed based on vector type reference data such as digitized object or parcel boundary data. However, this assessment was ignored by researchers for land cover classification using per pixel classification method as it was assumed to be corrected during geometric correction process (Radoux *et al.*, 2007).

Generally this study was conducted to assess the forest encroachment area, its extent and size, especially in Mentigi Forest Reserve, by using remote sensing method. To do so, high resolution remote sensing data was used in order to detect the small scale encroachments that have occurred. This study also emphasizes the use of cadastral parcel in remote sensing field. Cadastral parcel were used to provide delineation of accurate boundary of forest area and to aid for detecting the encroached area. High accuracy cadastral parcel were also used as reference data in assessing the boundary accuracy of the land cover classification result that are derived from high resolution remote sensing data.

1.2 Problem Statement

High demand for land and the wealth of the rain forest leads to forest encroachment and depletion in Malaysia. Since the demand of agricultural activity and demographic pressure increased, land becoming a limited resource and people tend to extend their activity across the forest border and encroached the forest area. This encroachment is severely occurred in developing area that is surrounded by forest such as Cameron Highlands, Malaysia.

Rampant forest encroachments in Cameron Highlands area have call upon responsible government agency to act against it. Several natural disaster caused by this problem shows prevention and control must be taken into action. Forest monitoring led by the local authorities by using field survey, aerial monitoring. Very few works using remote sensing and unmanned aerial vehicle (UAV) nevertheless the result have not disclosed to the public yet. Continuous research is required on the capability and achievable accuracy of the datasets and techniques.

Encroachment of forest reserve has also been reported by local newspapers (Sinar Harian, 2013). Mentigi Reserve Forest in Cameron highlands is one of the forest in Malaysia surrounded by human activities. This forest accommodates a hydroelectric tunnel that is used to tunnel water to the hydroelectric dam nearby. Encroachment activities within this reserved forest if unchecked can cause disaster to this tunnel facility and residential area surrounding the forest reserve area. Because of this problem, government need to take actions by monitoring and solving the forest encroachment problem.

In this study, remote sensing technique has been used for retrieving information on forest encroachment activities. The capability of remote sensing technique to observe the earth from above, are very suitable in forest monitoring application (Geist and Lambin, 2002; Malthus *et al.*, 2002; Suárez *et al.*, 2005;

Mendelsohn *et al.*, 2007; Olsson *et al.*, 2012). Continuous surveys of the forest boundary are one of the available techniques that might assist in monitoring any encroachment activities. Multi temporal data of remote sensing will provide continuity of monitoring process. In forest encroachment monitoring, additional data need to be used together with remote sensing data to display the encroachment area.

The capability of remote sensing in detecting and mapping the forest area information cannot be questioned. However the produced map does not came with ownership or property information. The size of the encroachment in individual property is not known. For example to detect the forest reserve location in remote sensing map, additional data to at least show the boundary of forest is needed. This data can be in the form of forest boundary data, topography map and so on. Furthermore, the accuracy of this additional data is questionable. Thus, the highly accurate data is needed for this purpose. This study suggest the used of cadastral parcel together with remote sensing data in retrieving information on encroached areas.

The cadastral parcel which is acquired using survey method by Department of Survey and Mapping, Malaysia (JUPEM) is known to have centimetre level positional accuracy. This data shows boundaries and provides information on individual parcels including lot number, area, bearing and distances, coordinates of some points and etc. However accuracy difference is an issue to investigate in order to use this data with remote sensing images. This is because the best spatial accuracy of remote sensing image can achieve is said to be 0.5 metre which is much lower than the accuracy of cadastral parcel (Malthus *et al.*, 2002). In this research a new technique was applied to carry out accuracy assessment between cadastral parcel and remote sensing result to check the compatibility between these two datasets.

The used of cadastral parcel in remote sensing for forest encroachment studies have not yet been reported before. The suitability to use these data together in forest encroachment mapping is also not known. In this study, the first stage is to determine the location and the extent of Mentigi Forest Reserve and its encroachment area from remote sensing image and then to use cadastral parcel to delineate the actual boundary of the forest in order to determine the actual size of the encroachment area. This study analyzed and made suggestions to local authority on steps need to be undertaken and to mitigate encroachment problem. Using this method also made the monitoring and mitigating process to be easier, faster and effective.

1.3 Objective

The aim of this study is to assess the forest encroachment problem in Mentigi Forest Reserve, Cameron Highland using high resolution satellite imagery and cadastral parcel. There are three objectives to be achieved, which include:

1. To utilize cadastral parcel and remote sensing datasets to determine size and to map forest encroachment area in Mentigi Forest Reserve.
2. To evaluate the accuracy of forest boundary derived from classification of different spatial resolution remote sensing datasets with reference to cadastral parcel.
3. To analyse forest cover changes map and forest encroachment map of area surrounding the Mentigi Forest Reserve.

1.4 Research Question

This study was carried out with the following research question:

i. How remote sensing data and cadastral parcel can be used to determine the size of forest encroachment?
ii. How cadastral parcel can be used to assess the accuracies of boundaries of classified forest produced from various resolution remote sensing datasets?
iii. How serious is forest encroachment problem in Mentigi Forest Reserve area and how much changes occurred to the forest reserve and also the surrounding area between 2001 and 2010?

1.5 Scope of study

In this study, forest encroachment mapping will be focused on Mentigi Forest Reserve area in Cameroon Highland, Pahang, Malaysia. This area is chosen due to current issue on encroachment of the government land by vegetable farmers. Remote sensing techniques has been used by many researchers in monitoring land cover changes including changes in the forested area all over the world and it was found to be as reliable as ground survey method (Toomey *et al.*, 2005; Suárez *et al.*, 2005; Tejaswi, 2007). Therefore, remote sensing technique was used in this study where, multispectral satellite images were used to classify the land cover of the study.

Based on previous study that has been done by numerous researchers, classification results are better if a few classification methods are combined. This so called hybrid classification was used to extract high quality land cover information. This satellite datasets also have different spatial resolutions. This research investigates the suitability of different satellites and resolutions in forest encroachment detection and boundary assessment. This different resolutions datasets are obtained from different satellites which is IKONOS and SPOT 5.

In Malaysia, any activity in government land that includes forest area without lawful authority as stated in Section 1.1 is considered as forest encroachment. Not all of these encroachment activities can be detected using remote sensing technique. Activities such as digging, precious rock finding, and small digging cannot easily be detected by remote sensing unless it effect the forest trees or the forest health. Therefore, the forest encroachment in this study cover only forest opening which might happen either near to the boundary of the forest or deep inside the forest area. This forest opening that may be caused by forest conversion for agriculture activities that can be detected, mapped and assessed in this study.

The task to map the forest encroachment area requires additional data to show the actual legal boundary of the forest as discussed before in Section 1.1. Therefore, high accuracy cadastral parcel was used for this purpose. These cadastral parcels need to be in the same projection with remote sensing images. The assessment is to check how close is the boundary of the forest from different resolution images compared to cadastral parcel. Cadastral parcel was also used to determine the size of Mentigi Forest Reserve area.

1.6 Significance of Study

This study aims to produce a map on forest encroachment and changes between 2001 and 2010 for the Mentigi Forest Reserve and its surroundings. This map was useful in monitoring the forest encroachment problem in the study area.

The used of multispectral remote sensing imagery provide help in extracting land cover information for the study area. High spatial resolution of satellite image also provide aid in assessing the small encroachment area that have happened especially the one that caused by agriculture activities. This small encroachment area otherwise might be hard to be detected using medium and low spatial resolution imagery.

Cadastral parcel was used with remote sensing imagery to locate the actual location of Mentigi Forest Reserve area. The boundary of this government forest area cannot be simply identified using remote sensing technique alone since it always have common borders with adjacent forest in other individual parcel. Cadastral parcel was also used to determine the original area of Mentigi Forest Reserve thereby determine the size of the encroachment area. Furthermore, difference resolutions remote sensing data produced results with different accuracy. This study also investigates the boundary accuracy of different resolution images by using cadastral parcel as reference data.

The method and technique that were applied in this study will help the authorities in monitoring forest and land encroachment activities. The method used and result achieved for the suitability assessment and accuracy assessment between cadastral parcel and remote sensing can be used as a reference to other researchers for further studies.

1.7 Organization of Thesis

This thesis comprises of five chapters namely Introduction (Chapter 1), Literature Review (Chapter 2), Methodology (Chapter 3), Results and Discussions (Chapter 4), and Conclusion and Recommendation (Chapter 5). Each chapter describes the details of the topic.

Chapter 1 introduces the overall idea of the study. This chapter discusses the background of study, problem statement, objective, scope and limitation, research question and significant of study.

Some concept and previous research of study have been discussed in details in Chapter 2. This chapter reviews the related concepts from papers on the previous studies to show the significant and importance of this study. In order to strengthen the idea of this study, various issues, methods and techniques, experiments, results, analysis and discussion, and problems or recommendations from previous studies were reviewed in this chapter.

Chapter 3 focuses on the material and method used in this study. All the techniques and processes used for pre-processing, post-processing, accuracy assessment and analysis are discussed in detail in this chapter. A flowchart of the methodology is presented to describe the workflow of this study.

Chapter 4 presents and discusses the results obtained in this study. In this chapter, all the outputs from pre-processing to the accuracy assessment were analysed.

Chapter 5 discusses some critical issues, concludes the study and make recommendations for further or future research.

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