Land cover change mapping using high resolution satellites and unmanned aerial vehicle

N F H Jumaat, Baharin Ahmad and Hafsat Saleh Dutsenwai

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

fatinani31@gmail.com

Abstract. Cameron Highlands is increasingly gaining popularity as a tourist attraction both locally and internationally. Unfortunately, due to the high demand of agricultural products and construction of new hotels and settlements, the area is now characterized by land scarcity. This research aims to assess the use of high resolution satellites images and Unmanned Aerial Vehicle (UAV) in detecting land use and land cover changes for a period of 12 years. The high-resolution satellite images of IKONOS and QuickBird were used together with a fixed wing Helang UAV. The object based classification method was applied to classify the images into seven land cover classes. Results indicate that land cover changes were detected in forest areas with a decrease from 196.1 hectares to 180.7 hectares and to 160.1 hectares from 2001 to 2007 and to 2013 respectively. Inversely, the built up areas increased from 47.8 hectares to 58.5 hectares and to 63.4 hectares from 2001 to 2007 and to 2013 respectively. During the same periods, there were slight increases in agriculture and grassland; the water body areas remained almost unchanged while in the bare soil areas there are slightly non-uniform changes. A large landslide area was detected in the UAV image.

1. Introduction

The use of land can be defined as all human activities which include agriculture, forestry and construction of buildings that change the processes of the surface including geochemistry, hydrology and biodiversity. On the other hand, cover refers to the physical and biological protection on the ground including water, vegetation, soil, and artificial structures [1]. Land use and land cover change is a dynamic physical change that occurs in any area on the earth surface. According to [2], rapid growth of urban areas is associated with increase in economic activities and thus provides many employment opportunities for the population

Remote sensing technology is widely used in the identification of changes in land use for a given period of time. According to [3] advancements in remote sensing technology enables the scientists to identify sustainable land processes and land cover changes at their study areas. As mentioned by [4] mapping of LULC has become one of the applications of remote sensing in updating LULC maps. Therefore, the availability and deployment of high-resolution images in classifying land use is very important as it produces more precise data measurement [5]. This can be seen in images of IKONOS multispectral images with a resolution of 4 meters and panchromatic image resolution of 1 meter. QuickBird satellite collects multi-spectral images at a resolution of 2.6 meters and panchromatic image at a resolution of 0.65 meters, both produced in natural or false colours. Due to its high resolution characteristic, it became the best choice for large scale mapping within a short time limit [6].

Other than high resolution satellite, UAV are capable to monitoring land use changes. According to [7], among the reasons for developing UAV technology are that it can be used to perform aerial photography at low elevations and can also be used during cloudy days or rainy seasons. This is because during the monsoon seasons, clouds are the main cause of disruptions during the collection of satellite images. Therefore, this technology is the most effective to be used in Malaysia being a country that has much cloud cover [8]. Moreover, UAV is also used in urban planning because of its potential to monitor and map inaccessible areas [9].

Object based analysis extracts information from remote sensing imagery and turns them into meaningful image objects based on object texture, shape and contextual relationship with other objects. This method assumes that each pixel is a separate object and may yield a more homogeneous and more accurate mapping product with more details in the class definition [10] [11]. Furthermore, object based change detection can capture more meaningful and detailed change information which models the actual geographic entities [12].

Many developments have been carried out in Cameron Highlands due to high demand as it is a famous tourist destination. Due to geographical factors, constructions still need to be carried out on slopes because there is limited availability of flat lands. These led to the conversion of the green areas into development areas. For example, [13] investigated the forest encroachment in Cameron Highlands by using multiple remote sensing datasets.

The aim of this study is to assess the capability of high-resolution satellite and UAV to detect land cover changes in Cameron Highlands. It also aimed to analyse the land cover changes in a period 12 years.

2. Methodology

The study area for this research is a part of Tanah Rata, Cameron Highlands which is located at the north western tip of Pahang. Cameron Highlands is one of the major tourist centres among the highlands of Malaysia. Its temperature is between 100c to 200c. The area is covered by forests, agricultural areas, developed areas and also dams and rivers. Recently, there have been many land use changes in the study area which caused some disasters. Figure 1 shows the study area.

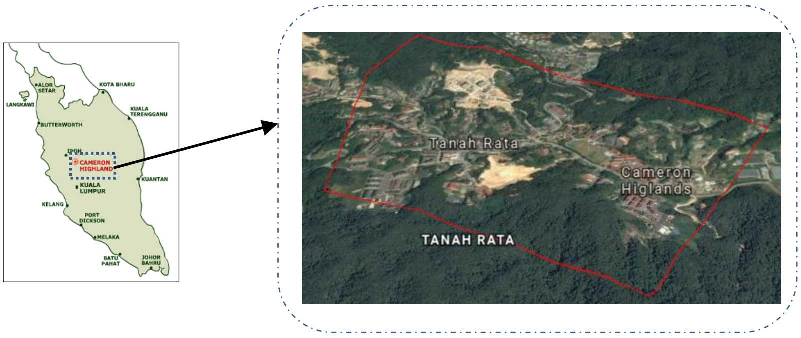

Figure 1. Location of study area

3. Data and Methodology

Selection of satellite data is an essential part of this study in order to meet the criteria for mapping land use changes in the study area. For this study, IKONOS imagery which was acquired on March 2001 and satellite QuickBird imagery acquired on March 2007 were selected as high-resolution images that allow large-scale mapping. For UAV data images acquired on November 2013, a total of 591 images were used to produce an orthophoto for the study area.

Figure 2 shows the methods used to fulfill the objectives of this research. The methodology is divided into several stages including; data acquisition, pre-processing, processing, data analysis and result.

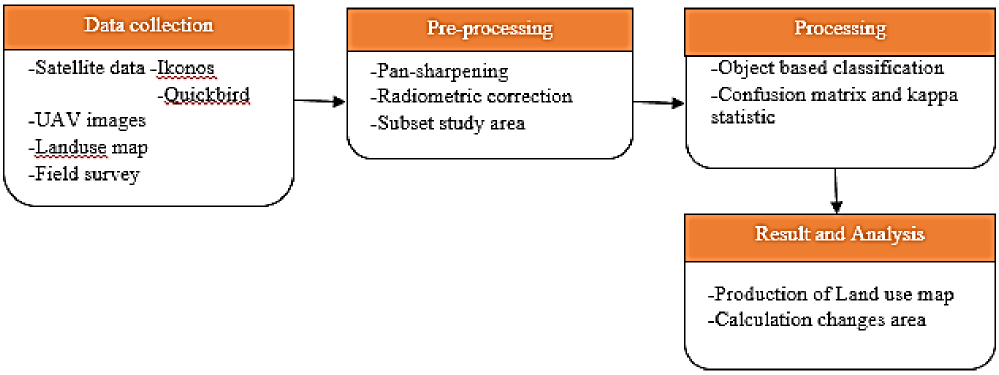

Figure 2. Flow chart of methodology for land use change detection

3.1. Pre-processing
Data pre-processing includes pan-sharpening, radiometric correction, geometric correction, orthorectification and subsetting of the study area. In producing the orthophoto of the UAV, each image was mosaicked after the process of building geometry in the Agisoft software. It was ensured that a sufficient number of overlapping images was used in order to produce an orthophoto image with high resolution. In this study, the projection used to register the image is RSO projection in GDM 2000 datum in the 3rd order polynomial using the nearest neighbor resampling technique.

3.2. Processing

3.2.1. Object based classification. This classification technique was carried out based on samples that were obtained from the data of the existing land use. In eCognition software, the first step in object-based classification is segmentation of the image. The segmentation process in eCognition software allows the users to define specific parameters that influence size and shape of the resulting image segments. A total of six classes were defined, namely agriculture, water body, forests, bare soil, grass, urban area and landslide.

3.2.2. Classification assessment. Accuracy analysis was carried out for each of the classification of satellite data to check the level of accuracy of spectral classes generated compared to the actual information. The assessment was based on the percentage of overall accuracy, kappa coefficient, commission and omission errors, and user and producer accuracies.

3.3. Analysis
In data analysis, quantitative analysis was carried out by calculating areas of land cover changes between 2001 until 2013. Area for each type of land use was calculated to see clearly how the area has changed. To ease the calculation of the affected areas, the data was converted from raster to vector. Land cover change analysis and mapping was processed in the ArcGIS software.

4. Results and Discussion

4.1. Land cover classification
The object based classification technique was carried out based on samples that were obtained from the data of the existing land use. The samples were used to select the training area on the image in order to classify it based on the training area. This classification technique was applied to all the satellite images and the UAV orthophoto to extract land use information for temporal data from 2001, 2007 and 2013. The process was split into two steps: segmentation and classification. The segmentation was performed using the following parameters as shown in Table 1.

Table 1. Details of segmentation

Image	Scale parameter	Shape	Smoothness	Compactness
IKONOS	50	0.3	0.7	0.6
QuickBird	50	0.3	0.7	0.6
UAV	100	0.3	0.7	0.6

Based on the produced land cover maps in Figures 3, 4 and 5, land cover for forest areas dominated the southern and northern parts of the study area. As for the urban areas, they are concentrated in the central part, i.e. the city area which includes placement, road network, industries and mixed development. There are agricultural areas in some parts including tea plantations and vegetable farming which are among the major sources of attraction and economic resources in the study area.

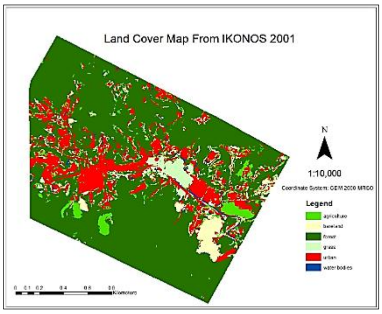

Figure 3. Land cover map from IKONOS

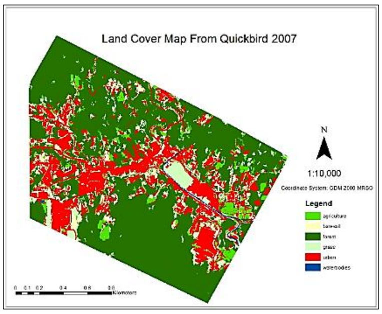

Figure 4. Land cover map from QuickBird

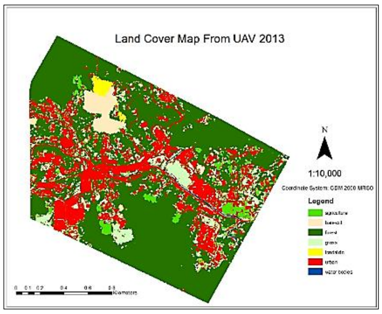

Figure 5. Land cover map from UAV

4.2. Accuracy assessment
In order to evaluate the performance of the classification, accuracy assessment was conducted with the reference as the raw satellite and UAV images. Overall accuracy and kappa coefficient for classified images are shown in Table 2. The classified image (2013) for UAV has the highest overall accuracy and kappa coefficient which 93.80% and 0.928 followed by 2001 for IKONOS with 86.67% and 0.840 and then 2007 for Quickbird with overall accuracy 83.89% and kappa 0.807.

Table 2. Overall accuracy and kappa coefficient

Image	Overall accuracy	Kappa coefficient
IKONOS	86.67%	0.840
Quickbird	83.89%	0.807
UAV	93.80%	0.928

4.3. Land cover changes
In the past 12 years, changes have occurred for each land use. Among the factors that contributed to the land use changes are physical, economic and environmental factors. They contributed to changes in land use for a period of 12 years. Figure 6 (a) shows the pattern of change in the forest land use. In 2001, extensive forest area was 196.08ha which decreased in 2007 and 2013 to 180.73ha and 160.09ha respectively. New housing estate development, unplanned industries and land clearance for agriculture are part of the causes of changes in the forest land use.

As shown in Figure 6 (b), bare land in 2001 covered an area of 10.43ha which is higher compared to the year 2007 having area coverage of 5.66ha. This is because, there are new construction sites which started in 2001 and were completed in 2007. Similar to 2001, the area of bare land in 2013 also has high area coverage of 11.13ha due to on-going constructions. Furthermore, it is clear that the developed area has steadily increased after a period of 12 years. Subsequently, Figure 6 (c) shows that the pattern of change is steadily increasing in agriculture area. Figure 6 (d) shows the pattern of grass area changes where the total area of grass in 2001, 2007 and 2013 were 22.21ha, 21.90ha and 27.56ha respectively.

Furthermore, in Figure 6 (e), it is clear that the developed area has increased steadily. In 2001, the urban area covers 47.77ha while in 2007 and 2013 they were 58.25ha and 63.43ha respectively. Construction of residential and industrial sites is ongoing to cater for the increased demands from 2001 to 2013. For water bodies, Figure 6 (f) shows that the pattern of change is small and negligible because water bodies are also represented by drainage which was unchanged over the years.

For the landslides class, it did not occur for the period 2001 to 2007 (Figure 6 (g)). However, in 2013 there were landslides in the study area covering 3.66ha. For landslides land use, it did not occur from 2001 to 2007. However, in 2013 there were landslides in the study area covering 3.66ha.

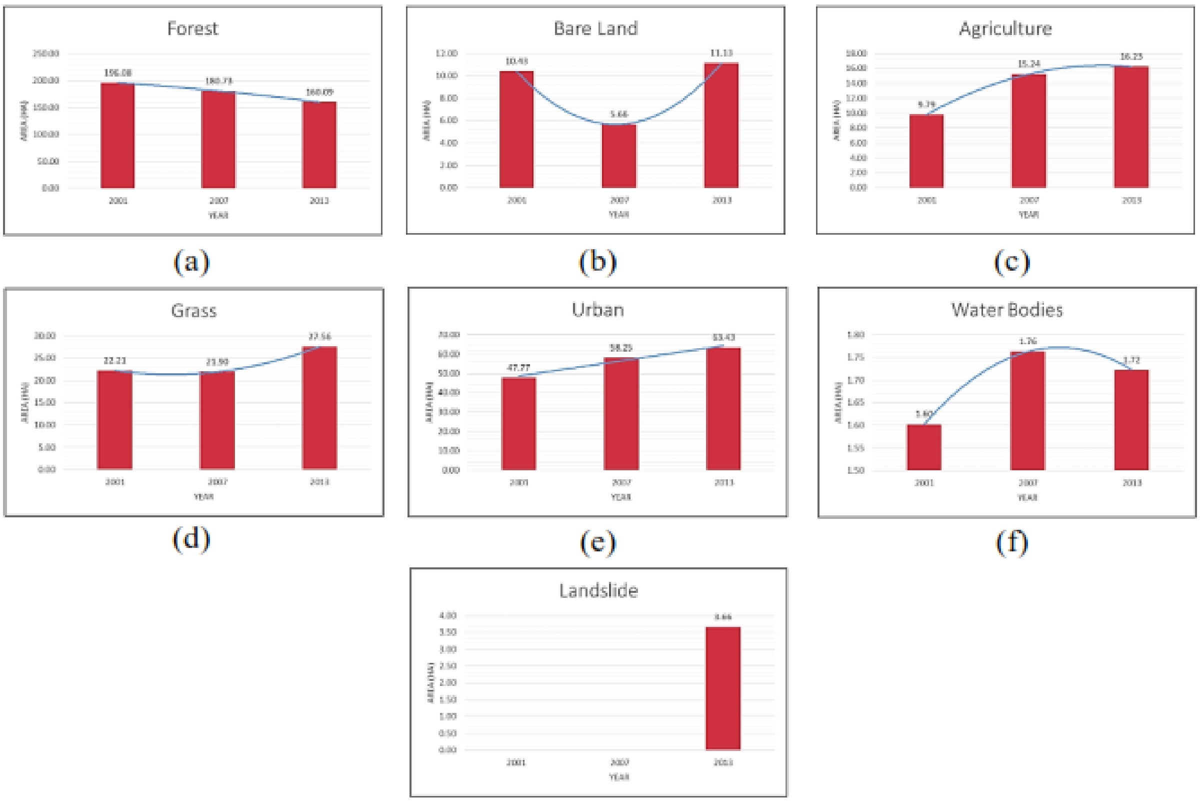

Figure 6. The percentage of area for the year 2001, 2007 and 2013 by class: (a) forest; (b) bare land; (c) agriculture; (d) grass; (e) urban; (f) water bodies; (g) landslide

5. Conclusion

This study has shown that the use of high resolution satellites such as IKONOS and QuickBird as well as UAV technology, is an effective way of mapping and detecting land cover changes.

The classified UAV image resulted in higher overall accuracy (93.80%) than IKONOS (86.67%) and QuickBird (83.89%). This shows the advantage of flying UAVs at low altitude as it can capture precise information especially in hilly terrains. The technique used in this study clearly shows in the pattern of changes that within 12 years, the forests have decreased whereas urban areas increased. For bare land areas, the change is inconsistent and depends on the completion of the developments.

Moreover, the grass and vegetation land uses change inconsistently depending on the planting season, while water bodies remain constant.

Acknowledgments
The authors wish to thank the Faculty of Geoinformation and Real Estate, UTM Skudai for their support and for providing facilities to complete this research. Last but not least, thanks also to Ministry of Higher Education for providing the grant (Q.J130000.2527.17H84).

References

[1] Ellis, E. (2010). Land-use and Land-cover Change. In: Encyclopedia of Earth. Eds.Cutler J. Cleveland Washington, D. C.: Environmental Information Coalition, National Council for Science and the Environment
[2] Goetz, S. J. and Jantz, C. A. (2004). Integrated Analysis of Ecosystem Interactions With Land Use Change: The Chesapeake Bay Watershed. Ecosystems and Land Use Change. *Geophysical Monograph Series*, **153**(1) pp 265-275
[3] Herold, M., Woodcock, C., Di Gregorio, A., Mayaux, P., Belward, A., Latham, J. and Schmullius, C. C. (2006). A Joint Initiative for Harmonization and Validation of Land Cover Datasets. *IEEE Trans. Geosci. Remote Sens.*, **44** pp. 1719-1727
[4] Lo, C.P., and Choi, J., (2004). A hybrid approach to urban land use/cover mapping using Landsat 7 enhanced thematic mapper plus (ETM+) images. *International Journal Remote Sensing*. **25** (14) pp. 2687–2700
[5] Franklin, S. E and Wulder, M. A. (2002). Remote sensing methods in medium spatial resolution satellite data land cover classification of large areas. *Progress in Physical Geography: Earth and Environment*, **26**(2) pp. 173-205
[6] Parcharidis, I., Foumelis, M., Papageorgiou, E., Segou, M., and Sakkas, V. (2005). Orthorectification and assessment of QuickBird imagery using D-GPS measurements over paros urban area. *Proc. Int. society for photogrammetry and remote sensing* 2005. Tucson, Arizona, USA: Joint Conference
[7] Lin, Z. (2008).UAV for Mapping–Low Altitude Photogrammetric Survey. *The International Archived of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXVII. Part B1. Beijing 1183
[8] Azmi, S. M., Ahmad, B., and Ahmad, A. (2014). Accuracy assessment of topographic mapping using UAV image integrated with satellite images. *IOP Conference Series: Earth Environmental Science* (1 ed., Vol. 18)
[9] Noor, N. M., and Rosni, N. A. (2016). The Evolution of Remote Sensing UAVs/Drones Applications in the Urban Planning Perspectives: A Review.
[10] Willhauck, G. (2000). Comparison of object oriented classification techniques and standard image analysis for the use of change detection between SPOT multispectral satellite images and aerial photos, vol.XXXIII.
[11] Herold, M., Scepan, J. and Clarke, K.C. (2002). The use of remote sensing and landscape metrics to describe structures and changes in urban land uses. *Environment and Planning A*, **34** pp. 1443–1458
[12] Chen, G., Hay, G. J., and, L. M. T. C., and Wulder, M. A. (2012). Object-based Change Detection. *International Journal of Remote Sensing*, **33**(14) pp. 4434-4457
[13] Zin, M. H. M., and Ahmad, B. (2015). Assessment of forest encroachment using remote sensing technique. Case study: Mentigi forest reserve, cameron highlands. *Jurnal Teknologi*, **73**(5) pp. 33-37