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MODIS: An Alternative for Updating Land Use and Land Cover in Large River Basin

Manithaphone Mahaxay[1*] **Wanchai Arunpraparut[1]**
Yongyut Trisurat[1] **Nipon Tangtham[2]**

[1]Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand.
[2]Forest Research Center, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand.
*Corresponding Author, E-mail: manithaphone@gmail.com

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ABSTRACT

Land use and land cover (LULC) information is essential for effective management of land resources, such as water. However, mapping of LULC at regional or large river basin scale based on high-resolution satellite image is usually expensive and time consuming. This research attempts to map the status of LULC in 2010 based on existing LULC in 2003 that was generated from Landsat. The mapping was undertaken in Tonle Sap basin, located in the northwest of Cambodia that covers an area of about 80,000 km^2. A conventional maximum likelihood classification was performed on Moderate-resolution Imaging Spectroradiometer (MODIS) imagery. The MODIS land cover products were evaluated using existing Landsat-TM based land cover maps in 2003 as a major reference data. Results showed that the MODIS classification was more successful at mapping the forested area and less successful at mapping the shrubland and upland crop. Small habitats (e.g., settlement area), which in many cases occupy small community areas that are smaller than the MODIS pixels, could not be identified. Accuracy assessment, based on comparison between classified LULC 2003 based on MODIS and the existing Landsat based LULC 2003, shows that overall accuracy was more than 80% and the Kappa index obtained was 0.81, which is considered as an acceptable level. This study showed the benefits of using MODIS satellite imagery that provide new options for regional land use and land cover mapping.

Keywords: MODIS, Land Use and Land Cover, Remote Sensing, Image Processing

INTRODUCTION

Up-to-date knowledge of land use and land cover (LULC) is an important tool for the various planning authorities that have responsibilities for the management of territory at a regional level. Among others, remote sensing and Geographic Information Systems (GIS) are known tools for watershed ecosystem and land resources management.

High- resolution satellite-based LULC has been widely used. Large regions can be observed, and its expanding capability allows for highly detailed images of an area to be viewed. According to Wilkie and Finn (1996), remote sensing increases our ability to view the world as a single entity as well as numerous sections of the whole. One benefit of remote sensing is the temporal advantage. Remote sensing provides a broad spectral viewing capability that allows the user to observe the differences in landscape that might not be apparent from just the visible spectrum and the naked eye (Usher and Truax, 2001). Another benefit is that traditional ground methods of land use mapping are labor intensive. More importantly, remote sensing becomes the only method of obtaining the required data in inaccessible areas (Mac Alister and Mahaxay, 2007).

The common satellite imagery that have been used for land resources management and mapping are Landsat, ASTER, ALI, Quick bird-2, IKONOS-2, WorldView2, Spot5, AVHRR, and MODIS. Each sensor has its own advantages and disadvantages. However, to map the large river basin of Tonle Sap the use of high-resolution satellite image becomes limited. The major problem with high spatial resolution satellite images (e.g. Landsat) is that imagery is not available very often (i.e., every 16 days or longer) and the coverage area is relatively small (swath width 185 km), while images of lower spatial resolution from MODIS are available daily and one image covers a relatively large area (swath width 2,330 km) (Hong *et al.*, 2011). MODIS surface reflectance has similar spectral band as Landsat. Because the first seven bands of MODIS were designed to simulate the Landsat sensor except for the spatial resolution, users can view MODIS imagery much the same way as Landsat imagery (Clark *et al.*, 2004). Among others, MODIS has potential capability to overcome the limitation of LULC mapping in large river basins. MODIS imagery showed capability to provide economically viable updated imageries and integrated land use mapping in tropical forest regions (Razali *et al.*, 2014). MODIS provides significant new opportunities and challenges for remote sensing-based land cover mapping research (Friedl *et al.*, 2002) and found to be quite useful for broad-scale land cover mapping (Giri and Jenkins, 2005). The other wide field of view instruments such as MODIS have full global coverage within a few days. MODIS is suitable for mapping land cover type (i.e. urban area, classes of vegetation, water area, etc.) at global, continental or national scale (Xie *et al.*, 2008). Another advantage of MODIS is that MODIS data is freely available for downloading from a number of sources (e.g., USGS through EROS Data Center, Global Land Cover Facility (GLCF), University of Maryland). The cost involved is only the cost of downloading large volumes of data.

Image classification is one of the most important phases of image analysis process (Anderson *et al.*, 1976). Processing of satellite image always involves sophisticated, complex procedures and high professional skill with image processing. Effective image processing also involves field data verification which can strain time and resources as well.

The objective of this study is to assess the potential capability of MODIS for LULC quick updating in the large river basin. Tonle Sap basin was selected as the case study. A simple, quick, non-sophisticated, non-complex, less computational, but reliable, image processing methodology was developed. High spatial resolution imagery is difficult due to the cost and time involved in processing large number of images required (Knight and Voth, 2011). Processing finer resolution satellite image involves high cost (Perera, 2013). It is expected that this methodology is repeatable within other large river basins. The aim of this paper is to demonstrate the capability of MODIS and the usefulness of this simple cost-effective remote sensing image processing tool for LULC updating.

MATERIALS AND METHODS

Study area

Tonle Sap Lake Basin is located in the northwest part of Cambodia at approximately latitude 102° 15' to 105° 50'E and longitude 11° 40' to 14° 28'N. It is a sub-catchment of the Mekong basin with a total drainage area of approximately 85,786 km^2,including a permanent lake area of about 2,350 km^2. The Tonle Sap Lake Basin is approximately 10.8% of the total area of the Mekong basin (Mekong River Commission, 2003). The majority of the catchment is located in Cambodia, and only 5% is in Thailand (Figure 1).

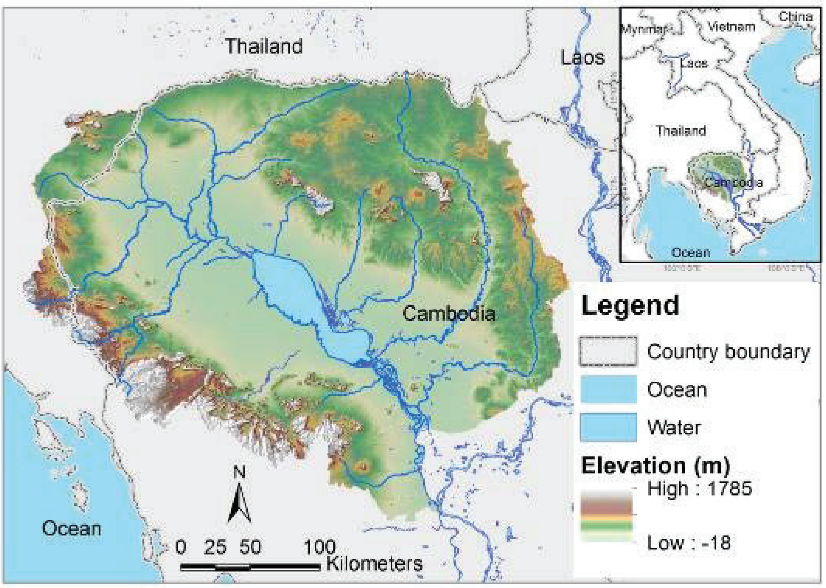

Figure 1 Tonle Sap Lake Basin.

Ground altitudes range from 1 to 1,500 meters above sea level. About one third of the area is covered by forests that consist of a mixture of deciduous trees. There are agricultural areas and many small settlements as well.

MODIS imagery and other data

To update LULC using MODIS data, an existing LULC map and MODIS image were used. MODIS 8-days composite MODIS Surface Reflectance Product (MOD09A1) of 2003 and 2010 had been acquired from NASA ftp server (ftp://e4ftl01u.ecs.nasa.gov/) for this purpose. In the production of MOD09A1, atmospheric correction for gases, thin cirrus clouds and aerosols are implemented (Vermote and Vermeulen, 1999). The other referenced data, such as, existing land use 2003, wetland, inundation, topography (DEM), aerial photos, digital (scanned) topographic maps, and some field data, were also used as an important backup data for image classification and verification of results. The existing land use 2003 derived from Landsat used as reference for MODIS image classification is showed in Table 2. Some limited field survey data and reports were also important for verification of results.

MODIS has special characteristics. MODIS Terra and Aqua scans the Earth twice daily. Although MODIS is loaded on a new generation Terra Earth Observation System (EOS), it has a coarser spatial resolution than Landsat, and has higher spatial, temporal and spectral resolution than AVHRR, which make it more capable of timely and dynamic monitoring of LULC. The MODIS surface reflectance 8-day composite with 500-meters resolution (MOD09A1) is explained in Table 1.

Table 1 Description of 7 bands MODIS 8-day composite.

Band	Wavelength (µm)	Description
1	620-670	Red
2	841-876	Near-infrared
3	459-479	Blue
4	545-565	Green
5	1230-1250	Short wave infrared
6	1628-1652	Short wave infrared
7	2105-2155	Short wave infrared

High quality, cloud free mosaics are produced at 8-day, 16-day and 32-day intervals and are presently available through the EOS Data Gateway at no cost to the user. Because of these characteristics of MODIS imagery, it is considered to have potential uses for LULC mapping in large river basins.

Image processing

For the purpose of LULC mapping, ArcGIS10.1 and ERDAS Imagine 8.2, which are powerful tools for image processing for extracting the LULC and post classification of LULC, were applied. For updating of LULC from existing 2003 dataset to 2010, the MODIS image of 2003 was used to create new 2003 LULC based on existing 2003 land use. The image was classified into 9 classes (Table 2) based on a modified version of the United State Geological Survey (USGS) (Anderson *et al.*, 1976) Levels I and II. Information at Levels I and II would generally be of interest to users who desire data on a nationwide, interstate, or statewide basis (Anderson *et al.*, 1976).

Table 2 Land use and land cover classes modified from USGS classification system.

No.	LULC class	
	Level I	**Level II**
1	Forest	Mixed deciduous
2		Evergreen
3		Shrub land
4		Plantation
5	Agriculture	Upland crops
6		Lowland paddy
7	Wetland	
8	Settlement area	
9	Water	

Similar to other optical imagery, the image processing methodology for MODIS involves two major steps, pre-processing and classification. In this study, geometric correction was not applied since this type of correction was automatically taken into account in the image transformation process by MODIS Tools. However, histogram equalization was used for image enhancement. Histogram equalization is a nonlinear stretch that redistributes pixel values so that there is approximately the same number of pixels with each value within a range. Histogram equalization is a process of automatically determining transformation function which produces an output image with a uniform histogram (Mathew and Kamatchi, 2013).

To support the data integration process or to make the GIS analysis possible, all images were registered to the Universal Transverse Mercator (UTM) coordinate system, zone 48 (north), World Geodetic System 1984 (WGS84) Datum. As raw MODIS image in HDF-EOS is not readable by common GIS applications, such as ArcInfo, ENVI and ERDAS, the HDF data format was transformed using "MODIS Reprojection Tool (MRT)" developed by USGS Earth Resources Observation and Science (EROS) Center in collaboration with the Department of Mathematics and Computer Science South Dakota School of Mines and Technology. The MRT tool can reformat HDF-EOS Swath and Grid data to HDF-EOS Grid, GeoTIFF format. This tool can also be used to re-project data from its original projection to other standard projections, to subset data, and to mosaic/stitch adjacent granules together. Using this tool, the raw MODIS data in HDF-EOS file format were converted into Geo-Tiff format in UTM48WGS84 projection system.

Image Classification

Classification is the process of assigning discrete pixels of a multispectral image to classes based upon their spectral characteristics (Wilkie and Finn, 1996). These spectral data are converted into land use and land cover classifications. Digital image classification also allocates image units (pixels) into a finite number of individual classes, or categories, based on the image digital number (DN) and a set of statistical criteria. The process of identifying image pixels with similar properties, organizing them into groups and assigning labels (e.g., habitat names) to those groups is also a form of classification (Green *et al.*, 2000). LULC classes can be analyzed using the unique signature of habitat types and statistical analysis algorithms. In this study, Maximum Likelihood Classification (MLC) method was applied. The MLC assumes that a pixel has a certain probability of belonging to a particular class. These probabilities are equal for all classes and the input data in each band follows the Gaussian (normal) distribution function (Lillesand *et al.*, 2004). The MLC method is most accurate compared to the minimum distance method (Patil *et al.*, 2012). The strong advantage of Maximum Likelihood method is its use of well-developed probability theory (Muzein, 2006). Figure 2 illustrates the process image classification using ERDAS Imagine software.

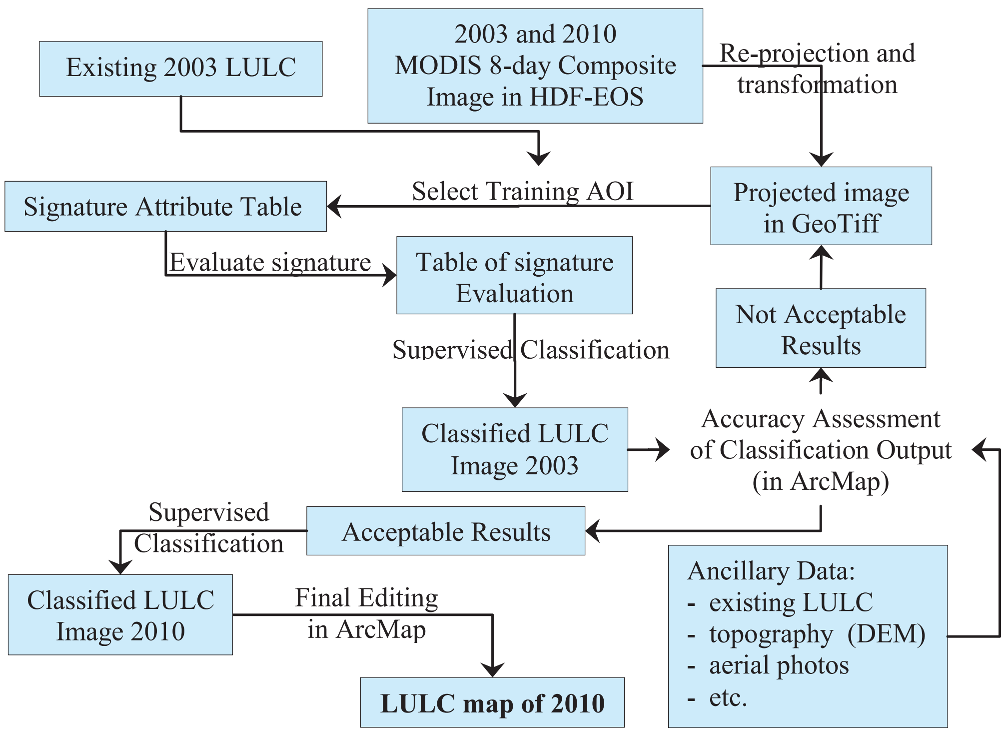

Figure 2 Flowchart showing stages in MODIS classification for LULC mapping..

An existing LULC map based on Landsat was used for training area selection. Aerial photos, Google map, and other maps were also used to confirm the candidate training areas as well as for cross-checking the image classification result. Unfortunately, for some of the classes, such as build-up area and plantation forests, only a limited number of training areas could be identified.

Post classification was performed to improve accuracy. Accuracy of image classification can be improved with the integration of data and/or information other than imagery (Gahegan and Franck, 1996) and (Westmoreland and Strow, 1992). The post-classification process involved confirmation of LULC classes using inundation map, existing GIS layers, elevation, and ortho-photo datasets.

Topographical data on elevation was used to discriminate between wetland and terrestrial ecosystem of dry forest and flooded forest. Final results about LULC characteristics were quantified in GIS.

Accuracy assessment

Accuracy is typically used to express the degree of correctness of thematic maps (Foody, 2002). An accuracy assessment quantifies how good the image classification was implemented. Due to unavailability of ground truth or reference data obtained at the time of image acquisition, an evaluation of the classification methods was performed using the stratified random scheme technique. Stratified Random Sample rules were used to derive assessment sample points using the equation developed by Fitzpatrick-Lins (1981):

$$N = \frac{Z^2 pq_t}{E^2}$$

where N = number of sample points; p = expected or calculated accuracy (%); q = 100 – p; E = allowable error; and Z = standard normal deviate for the 95% two-tail confidence level = 1.96.

A total of 204 sample points was obtained. Due to the variation of the number of polygons in each LULC class, the number of assessment points of each LULC class was set based on the proportion of numbers of polygons. As a result, the number of assessment points of each stratum were 14, 63, 47, 20, 2, 31, 16, 2, and 9, for upland crops, mixed deciduous, evergreen, shrub, plantation, lowland paddy, wetland, settlement area, and water, respectively. Accuracy assessment was conducted only for MODIS classification result of 2003 because: 1) existing LULC map was only available in 2003 which made other years of MODIS classification impossible to have a map of the same LULC year for validation; and 2) the classification process was made using the same procedure and the same training samples, and evaluation using one LULC datasets was considered to be sufficient.

A simple accuracy assessment was adopted based on the methodology developed by the Remote Sensing/GIS Programs, Center for Biodiversity and Conservation of the American Museum of Natural History on how to interpret accuracy statistics (Horning, 2004). The simple assessment procedure was also supplemented by comparing the classification output (by pixels) to the high-resolution air photo. The producer and the user accuracies, as well as the kappa statistics for each class, were calculated.

RESULTS AND DISCUSSION

Image classification results from maximum likelihood supervised classification were obtained. The image of the MODIS 2003 and 2010 were processed in the same way. Figures 3 illustrates the LULC maps after post-classification created from MODIS imageries of 2003 and 2010 compared with the existing land use map of 2003 from Landsat.

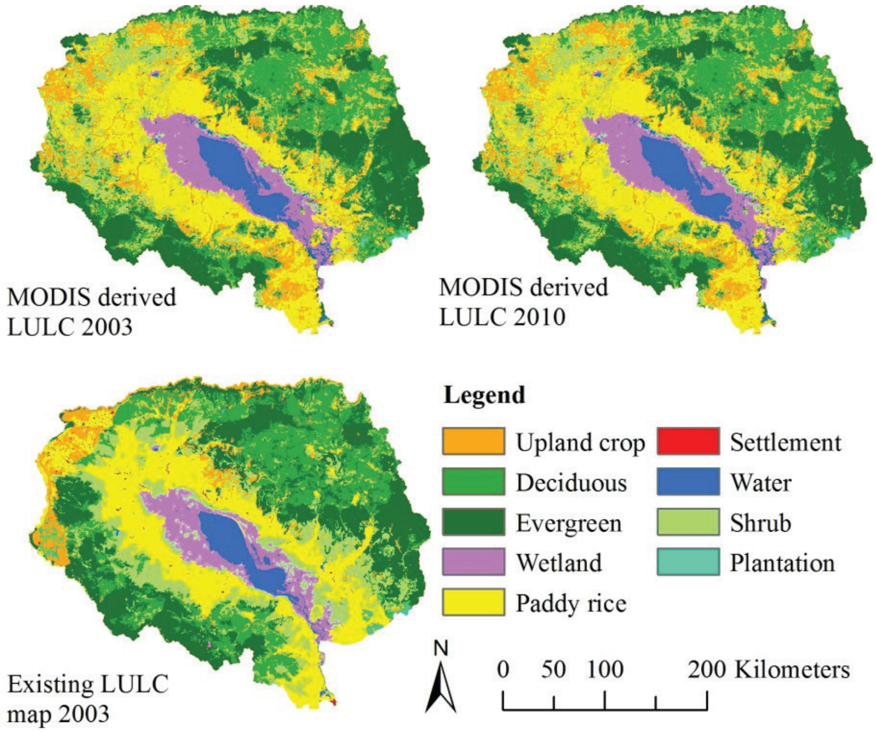

Figure 3 Existing Land Use map and MODIS Land Use and Land Cover classification results.

There were some limitations in selecting the training area. First of all, using the same number of training area per LULC class could not be performed. Areas of each LULC class are different; some LULC classes take a large proportion of the study area. Secondly, since MODIS image resolution is too big compared to the size of cities in Cambodia, there are not many urban areas in this study area. As a result, the settlement areas that are smaller than one MODIS image pixel were not classified as settlement. Figure 4 illustrates the MODIS image resolution versus settlement size compared to Google satellite image resolution. In this case, the number of training areas of settlement class selected was very small.

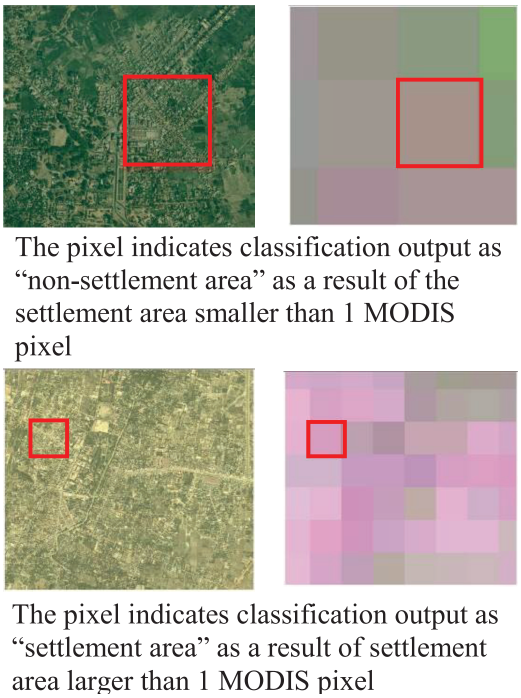

Figure 4 Settlement areas compared in MODIS and Google satellite images.

Classification results successfully produced 9 classes: evergreen forest, deciduous mixed forest, plantation forest, shrub and grassland, upland crop, paddy field, wetland, water, and built-up area. Post-classification proved to be a crucial step to facilitate the improvement of classification accuracy. Classification results of MODIS 2003 and 2010 are shown in table 3.

Table 3 Land use and land cover classification results.

No.	LULC class	Area (Km^2)		
		Existing LULC 2003	Classified MODIS 2003	Classified MODIS 2010
1	Mixed deciduous	17,800	25,319	17,722
2	Evergreen	20,354	19,116	17,436
3	Shrub land	14,910	10,288	10,852
4	Plantation	490	179	179
5	Upland crops	20,135	7,283	13,982
6	Lowland paddy	1,179	14,301	16,315
7	Wetland	5,324	5,970	5,970
8	Settlement area	249	48	48
9	Water	2,912	3,348	3,348
10	Others	2,499		

Accuracy assessment was statistically done for LULC classification output of 2003 compared with existing LULC 2003 produced from Landsat. The proportion of each LULC class in the resulting classification map and referenced map show similar trends (Figure 5).

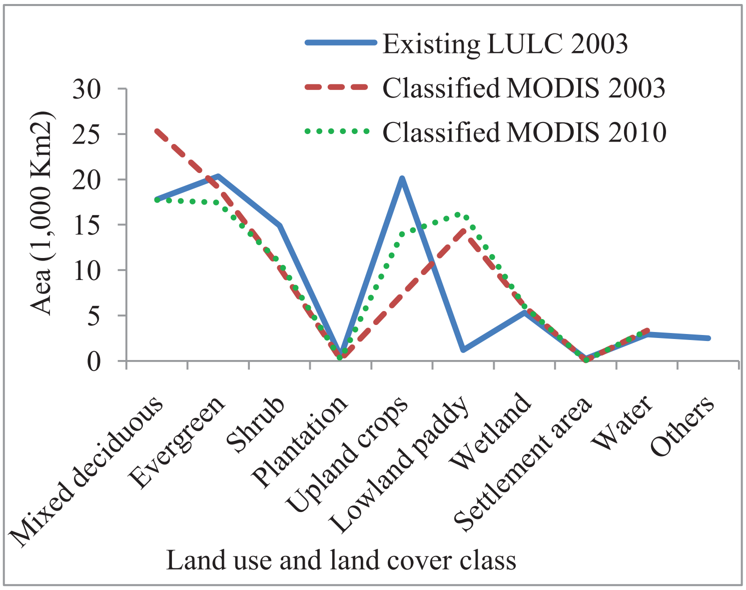

Figure 5 Comparison of referenced and classified land use and land cover area

However, except for proportion of the paddy area, the number of classified and referenced maps are big different. This is because the referenced map classified paddy as agriculture, while the classified map classified it as paddy.

Based on the methodology developed by Remote Sensing/GIS Programs, Center for Biodiversity and Conservation of the American Museum of Natural History on how to interpret accuracy statistics (Horning, 2004), accuracy assessment results were obtained. Overall accuracy was as high as 84.80%, and Producer's accuracy and Consumer's accuracy were 87.02% and 86.17% respectively. The results of the accuracy assessment are given in Table 4.

In addition, a more detailed analysis was carried out based on the Kappa analysis. The Kappa index obtained was 0.81. Hence, this MODIS image classification result was more than satisfactory and the overall accuracy was higher than 80% of the minimum overall accuracy recommended by Olson (2008). Level of this accuracy assessment, which was not as high as 90%, was due to two main factors: first, the source of referenced data was inaccurate to some degree; and, second, temporal change of LULC pattern between different time of the year of MODIS image acquisition and time of referenced data as well.

Table 4 Accuracy assessment of 2003 MODIS classification result compared with referenced data.

		Classified MODIS image of 2003										
	LULC classes	**Evergreen forest**	**Deciduous forest**	**Shrub land**	**Plantation**	**Upland crop**	**Lowland paddy**	**Settlement area**	**Wetland**	**Water**	**Row total**	**User's Accuracy (%)**
Validation data from LULC 2003	Evergreen	43	6								49	87.76
	Deciduous	1	53	2							56	94.64
	Shrub land	2	4	15		1	1	2			25	60.00
	Plantation				2						2	100
	Upland crop	1		1		11	4				17	64.71
	Paddy			2		2	26				30	86.67
	Wetland							13		1	14	92.86
	Settlement								2		2	100
	Water							1		8	9	88.89
	Column total	47	63	20	2	14	31	16	2	9	204	
	Producer's accuracy (%)	91.49	84.13	75.00	100	78.57	83.87	81	100	88.89		84.80

Notes: The diagonal numbers 43, 53, 15, 2, 11, 26, 13, 2, 8 are coincident number of sample points between classified and referenced map.

Although the overall accuracy was 85% for the generalized map product, examination of the individual classes in the error matrix reveals that some classes were mapped better than others. Forest classes are all mapped very well. sShrub land and upland crop were poorly mapped compared to forest.

A classified image was produced as a thematic raster layer. For GIS analysis and mapping purposes, thematic LULC raster data was converted to a vector polygon feature (ESRI data format). To reduce disk space, a rough but useful rule to use when selecting imagery to discern attributes of given size is that the sensor must be able to detect objects one-half the size of the objective to be identified (Terri, *et al.,* 1997). The polygons less than 2 x 2 pixels or 1 x 1 km, were removed. In other words, the minimum mapping unit was set at 100 hectares.

MODIS imagery proved to be very affordable and successful by identifying and discriminating LULC classes at the large river basin level. The objective of the accuracy assessment was to quantitatively measure the accuracy of the MODIS-derived LULC map product. Nine LULC classes were successfully mapped. Hence, this MODIS image classification was more than satisfy as the overall accuracy was higher than 80% of the minimum overall accuracy based on the discussion and recommendation by Olson (2008). Using the available technologies, GIS analysis and moderate-resolution satellite image, such as, MODIS proved to be useful for creating LULC Level I and II classification maps at the basin-wide scale.

CONCLUSION

This research work aimed to develop an effective method to produce and update LULC mapping at river basin level with special emphasis on object oriented classification of two temporal images from MODIS. The study revealed the usefulness of remote sensing data and analysis techniques in the context of LULC mapping considering the level 1 and 2 of USGS LULC classification system. MODIS data provides new options for regional land cover mapping that are less labor-intensive than the high-resolution satellite image, e.g., Landsat. The research found that moderate-resolution satellite imagery was very useful for basin-wide scale LULC mapping; however, the following points should be considered for further research. Using cloud-free 8-days MODIS composite has an advantage in that it can reduce the time for cloud mask and image radiometric correction. The most time consuming process in generating LULC map from MODIS composite imagery is the selection of training sites because the composite image comes from multiple dates. The Digital Number (DN) of the composite image has been altered through the composition process that made the DN and is not uniform within a single scene. This may result in classification inaccuracy.

Although the overall accuracy obtained from the 2003 LULC map was shown to be 85%, which was a reasonable accuracy, the associated producer's and user's accuracies were questionable. The overall accuracy was doubtful since accuracy assessment was based on existing LULC and cross-checking with high-resolution aerial photo (rather than using the actual ground truth data). To improve the mapping accuracy, referenced data are crucial for selection of the training area. The selection of training area is key to the success for MLC. This includes not only proper training sample location and sufficient number of training sample, but also well distributed it is throughout the study area. Since the automate classification using maximum likelihood algorithm cannot be fully applied for the composite image, the issue that should be emphasized is the correction of the classification result based on reference data through the post-classification process.

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REFERENCES

Anderson, J.R., E.E. Hardy, J.T. Roach and R.E. Witmer. 1976. **A Land Use and Land Cover Classification System for Use with Remote Sensor Data**. United States Government Printing Office. Washington D.C.

Clark, J., Zajkowski T. and K. Lannom. 2004. Remote sensing imagery support for burned area emergency response teams on 2003 southern California wildfires. **Proceedings of the 2004 10th Biennial Forest Service Remote Sensing Applications Conference**. April 2004. Salt Lake City, UT.

Fitzpatrick-Lins, K. 1981. Comparison of Sampling Procedures and Data Analysis for a Land Use and Land Cover Map. **Photogrammetric Engineering & Remote Sensing** 55(4): 475 - 478.

Friedl, M.A., D.K. McIver, J.C.F. Hodges, X.Y. Zhanga, D. Muchoney, A.H. Strahler, C.E. Woodcock, S. Gopal, A. Schneider, A. Cooper, A. Baccini, F. Gaoa and C. Schaaf. 2002. Global land cover mapping from MODIS: algorithms and early results. ELSEVIER. **Remote Sensing of Environment** 83 (2002): 287 – 302.

Foody, G. 2002. “Status of Land Cover Classification of Accuracy Assessment,” **Remote Sensing of Environment** 80(2002): 185-201.

Gahegan, M. and J. Franck. 1996. A Model to Support the Integration of Image Understanding Techniques within a GIS, **Photogrammetric Engineering and Remote Sensing** 62(5): 483-490.

Giri, C. and C. Jenkins. 2005. Land cover mapping of Greater Mesoamerica using MODIS data. **Canadian Journal on Remote Sensing** 31(4): 274–282.

Green, E. P., Mumby P.J., Edwards A. J., Clark C. D.,(Ed. A. J. Edwards). 2000. **Remote Sensing Handbook for Tropical Coastal Management**. Coastal Management Sourcebooks 3, UNESCO, Paris.

Hong, S.H., J.M.H. Hendrickx and B. Borchers. 2011. Down-scaling of SEBAL derived evapotranspiration maps from MODIS (250m) to Landsat (30m) scale. **International Journal of Remote Sensing** 32 (21, 2011): 6457-6477.

Horning, N. 2004. **Remote Sensing Guides, Image Interpretation and Classification,**

Overview of accuracy assessment of land cover products. Center for Biodiversity and Conservation at the American Museum of Natural History, 2004. Available Source: http://biodiversityinformatics.amnh.org/content.php?content_id=131, accessed: January 15th, 2013.

Knight, J. and M. Voth. 2011. Mapping Impervious Cover Using Multi-Temporal MODIS NDVI Data. **IEEE Journal of Selected Topics in Applies Earth Observations and Remote Sensing** 4(2): 303-309.

Lillesand, T.M., R.W. Kiefer and J.W. Chipman. 2004. **Remote Sensing and Image Interpretation, 5th ed.** NY: Jonh Wiley and Sons, New York.

Mathew, A. A. and S. Kamatchi, 2013. Brightness and Resolution Enhancement of Satellite Images using SVD and DWT. **International Journal of Engineering Trends and Technology** 4(4): 712-718. Available source: http://www.ijettjournal.org, accessed: April 3, 2014.

Mc Alister, C. and M. Mahaxay. 2007. Mapping Wetlands in the Lower Mekong Basin Using LandsatETM Images and Field Survey Data. **Journal of Environmental Management** 90 (7): 2130-2137.

Mekong River Commission. 2003. **State of the Basin Report: 2003**. Mekong River Commission (MRC), Phnom Penh, Cambodia.

Muzein, B.S. 2006. Remote Sensing and GIS for Land Cover/ Land Use Change Detection and Analysis in the Semi-Natural Ecosystems and Agriculture Landscapes of the Central Ethiopian Rift Valley, **PhD Thesis. Institute of Photogrammetry and Remote Sensing**, Technology University of Dresden

Olson, C.E. Jr. 2008. Is 80% Accuracy Good Enough?, Pecora 17 – The Future of Land Imaging…Going Operational. **The 17th William T. Pecora Memorial Remote Sensing Symposium**, November 16-20, 2008, Denver, Colorado, Colorad Convention, Reno, NV, May 2006.

Patil, M. B., Desai2 C. G. and B. N. Umrikar . 2012. Image Classification Tool for Land Use /Land Cover Analysis: A Comparative Study of Maximum Likelihood and Minimum Distance Method. **International Journal of Geology, Earth and Environmental Sciences** 2 (3): 189-196. . Available source: http://www.cibtech.org/jgee.htm, accessed: April 10, 2014.

Perera, K. 2013. Application of Modis Data to Assess the Latest Forest Cover Changes of Sri Lanka. **Asian Journal of Geoinformatics** 13 (1): 1-8.

Razali, S.M., A. Marin, A.A. Nuruddin, H.Z.M. Shafri and H.A. Hamid. 2014. Capability of Integrated MODIS Imagery and ALOS for Oil Palm, Rubber and Forest Areas Mapping in Tropical Forest Regions. **Sensors 2014** 14(5): 8259-8282.

Terri, A. B., Getlein S., Jarrett J., Tripp S. and J. Moeller.1997. **Remote Sensing Users' Guide**, USAEC and TEC. USA.

Usher, J.M. and D.D. Truax. 2001. **Exploration of Remote Sensing Applicability Within Transportation**. Department of Civil Engineering. Mississippi State University.

Vermote, E. F. and A. Vermeulen. 1999. **Atmospheric correction algorithm: Spectral reflectance (MOD09), MODIS algorithm technical background document, version 4.0**. University of Maryland, Department of Geography.

Westmoreland, S. and D.A. Strow. 1992. Category Identification of Changed Land Use Polygons in an Integrated Image Processing Geographic Information System. **Photogrammetric Engineering and Remote Sensing** 58 (11): 1593-1599.

Wilkie, D.S. and J. T. Finn. 1996. Remote Sensing Imagery for Natural Resources Monitoring. **Columbia University Press**, New York.

Xie, Y., Sha Z. and M. Yu. 2008. Remote sensing imagery in vegetation mapping: a review. **Journal of Plant Ecology** 1 (1): 9-23.