ASSESSMENT OF FOREST LAND CHANGE IN SOUTHEAST PAHANG, MALAYSIA USING REMOTE SENSING TECHNIQUES

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Tropical forest has been recognized as mostly disturbed natural land cover which contribute to deprived ecological balance. Malaysia is one of the primary exports of palm oil and timber in Southeast Asia. Hence, the objectives of this research mainly to evaluate the deforestation activity and predict the future extent of forest land in the highly deforested area in Pahang. These could be achieved through; (1) assessing the deforestation dynamics in Southeast Pahang using remote sensing, and (2) predicting the future spatio-temporal deforestation using CA-Markov model for year 2025 and 2035. The most critical issue is that forest land are usually inaccessible, therefore, remote sensing (RS) and Geographical Information System (GIS) are the important tools and recent approach for forest cover monitoring.

The imageries from Landsat 5TM and 8 OLI satellite platforms were retrieved and categorized into four types of land cover including forest, non-forest vegetation, openland/ built-up, and waterbodies using Maximum Likelihood Classification (MLC). In addition, contour data was utilised to produce the elevation and slope maps, while Euclidean Distance analysis were applied to city centre, and Permanent Reserved Forest (PRF) for proximity maps. The overall accuracies are ranging from 83.7%, 80.9%, 85.6%, and 84.4% with Kappa value of 0.65, 0.65, 0.74, and 0.74 for 1990, 2000, 2010, and 2017 respectively.

The results from land change analysis show that state land had changed from 42% of total forest area in 1990 to 21% in 2017 with a steady negative change over time. Dipterocarp reserved forest are consistently exploited for

timber extraction, but the forest covers are able to be regenerated after more than 20 years from sustainable management practices. The distance to population centre has a positive relationship with deforestation, and the protected area have a clear restriction on deforestation in the area because forest loss inside protection region only happen after 20 years of study period compared to the outside of protected region. Furthermore, elevation and slope have similar effects on deforestation where the increase in their value will reduce the risk for deforestation. For land cover prediction, Markov chain integrated with cellular automata model were used for future forest land cover forecasting. The model calibrations achieved up to 62% accuracy for land cover prediction. The CA-Markov model prediction for year 2025 and 2035 suggests that the forest land cover will continuously reduce with 13 to 24 km^2/year rate.

Generally, state lands provide the highest level of deforestation in Rompin and Pekan district in both dipterocarp and peat swamp type, conversely the reserved forest in peat area are more protected compare to dipterocarp type. The comparison between using multiple and binary land cover as input suggest that the traditional CA-Markov model can simulate better when dealing with binary land cover. Other than that, the deforestation might be more than what were predicted in this study based on the standard error of the model.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN PERUBAHAN TANAH HUTAN DI TENGGARA PAHANG, MALAYSIA MENGGUNAKAN TEKNIK PENDERIAAN JAUH

Oleh

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Hutan tropikal telah diiktiraf sebagai litupan tanah semula jadi yang paling banyak diganggu yang menyumbang kepada pengurangan keseimbangan ekologi. Malaysia dikenali sebagai salah satu daripada eksport utama minyak kelapa sawit dan kayu balak di Asia Tenggara. Oleh itu, objektif kajian ini adalah untuk mengukur aktiviti penebangan hutan dan meramalkan tahap tanah hutan di masa hadapan di kawasan yang sangat terkesan di Pahang. Ini boleh dicapai melalui; (1) menilai dinamik penebangan hutan di Tenggara Pahang menggunakan penderiaan jarak jauh, dan (2) meramalkan ruang-masa penebangan hutan di masa depan menggunakan model CA-Markov untuk tahun 2025 dan 2035. Isu yang paling kritikal ialah tanah hutan biasanya tidak boleh diakses, oleh itu, penderiaan jarak jauh (RS) dan Sistem Maklumat Geografi (GIS) adalah alat penting dan pendekatan terbaik untuk pemantauan perlindungan hutan.

Imej-imej dari platfom satelit Landsat 5TM dan 8 OLI telah diambil dan dikategorikan kepada empat jenis litupan tanah termasuk hutan, tumbuh-tumbuhan bukan hutan, tanah lapang/binaan, dan badan air. Data kontur digunakan untuk menghasilkan peta ketinggian dan cerun, manakala analisis Euclidean Distance digunakan untuk penghasilan peta kedekatan bagi pusat penempatan dan Hutan Simpan Kekal (PRF). Ketepatan keseluruhan adalah dari 83.7%, 80.9%, 85.6%, dan 84.4% dengan nilai Kappa 0.65, 0.65, 0.74, dan 0.74 untuk tahun 1990, 2000, 2010 dan 2017.

Hasil analisa perubahan litupan tanah menunjukkan bahawa hutan tanah kerajaan berubah dari 42% daripada jumlah kawasan berhutan pada tahun 1990 kepada 21% pada tahun 2017 dengan perubahan negatif sepanjang masa tersebut. Hutan simpan Dipterokarp dieksploitasi secara konsisten

untuk pengeluaran kayu, tetapi litupan hutan dikawasan tersebut telah dijana semula setelah lebih dari 20 tahun dari pengurusan mampan yang diamalkan oleh jabatan hutan negeri. Jarak ke pusat penduduk mempunyai hubungan positif dengan penebangan hutan dan kawasan lindungan mempunyai batasan yang jelas bagi pemusnahan hutan di kawasan kajian kerana kawasan hutan di dalam kawasan hutan lindungan hanya berlaku selepas 20 tahun tempoh pengajian dijalankan berbanding dengan luar kawasan lindungan. Tambahan pula, ketinggian dan cerun mempunyai kesan yang sama terhadap penebangan hutan. Peningkatan nilai mereka akan mengurangkan risiko penebangan hutan. Untuk ramalan litupan tanah, rantaian Markov yang diintegrasikan dengan model cellular automata telah digunakan untuk meramal litupan hutan di masa depan. Kalibrasi model mencapai ketepatan 62% untuk ramalan litupan tanah. Ramalan model CA-Markov untuk tahun 2025 dan 2035 menunjukkan bahawa litupan tanah hutan akan terus berkurang dengan kadar 13 hingga 24 km^2/tahun.

Secara amnya, tanah kerajaan mempunyai tahap penebangan hutan tertinggi di daerah Rompin dan Pekan dalam hutan jenis Dipterokarp dan paya gambut, namun, hutan simpan di kawasan gambut lebih dilindungi berbanding jenis dipterokarp. Perbandingan antara penggunaan litupan tanah pelbagai dan binari sebagai input menunjukkan bahawa model CA-Markov tradisional boleh meramal dengan lebih baik apabila menggunakan litupan tanah binari. Selain itu, penebangan hutan mungkin lebih daripada apa yang diramal dalam kajian ini berdasarkan ralat piawai model tersebut.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ABG	Aboveground Biomass
CA	Cellular Automata
DID	Department of Irrigation and Drainage
DOA	Department of Agriculture
DOSM	Department of Statistics Malaysia
FAR	Forestry Annual Report
Fmask	Function of Mask
FNF	Forest-non-Forest
GIS	Geographic Information System
GLAS	Geoscience Laser Altimeter System
ITTO	International Tropical Timber Organization
JUPEM	Department of Survey and Mapping Malaysia
LCDM	Landsat Data Continuity Mission
LCM	Land Change Modeler
LDF	Lowland Dipterocarp Forest
LULC	Land Use and Land Cover
MCE	Multi-criterion Evaluation
Mg	Million Gram
Mg C	Million Gram Carbon
MHA	Million Hectares
MLC	Maximum Likelihood Classification
MLP	Multi-layer Perceptron
MLR	Multi Linear Regression
MOLA	Multi-Objective Land Allocation
MPOB	Malaysian Palm Oil Board
MSS	Multispectral Scanner
NDVI	Normalized Difference Vegetation Index
NEPcon	Nature Economy and People Connected
NFA	National Forestry Act
NFC	National Forestry Council
NLC	National Land Council
NIR	Near Infrared
OLI	Operational Land Imager
PCP	Potential Cloud Pixels
PM	Peninsular Malaysia
PRF	Permanent Reserved Forest
PSF	Peat Swamp Forest
RS	Remote Sensing
SAR	Synthetic-aperture Radar
SFM	Sustainable Forest Management
SMS	Selective Management System
SWIR	Shortwave Infrared
TIRS	Thermal Infrared Sensor
TOA	Top of Atmosphere
TM	Thematic Mapper

CHAPTER 1

INTRODUCTION

1.1 Background

Tropical forests are the richest, diverse, and most ecologically complex of land communities (Myers, 1992). Due to different geographical and physical conditions, there are different types of forest ecosystem, which in Peninsular Malaysia (PM) itself, covered by mountain dipterocarp, hill dipterocarp, lowland dipterocarp, peat swamp, and mangrove forest (Omar et al., 2017).

Malaysia, as one of tropical climate region, has been endowed with extensive areas of tropical forests which covered with vast of vegetation area and thousands species of flora and fauna together. The economics and technologies of this country are still rapidly expanding since the industrial era in 1970s, and along the development, in order to compete with the demands and supplies for human needs the natural resources exploitation such as deforestation is necessary. Even though there are already established rules and regulations for a sustainable forest resource management, there are still lack of practices and awareness about it. Urbanization, agricultural expansion, and forest products industry are some of the main factors for deforestation in tropical country which still needs to be concerned (Laurance, 1999; Geist and Lambin, 2002; Carr, 2004). Deforestation and forest degradation related to human activities and land resources are considered as a result from economic and developing measures. In therefore, as the world's population increases and development progresses, it is expected that demand for land will also increase in line with it. As a consequent, there will be a need of land conversion to urban and agriculture types, and ultimately natural forest area has to be exploited to fulfil the demand.

Living trees are the source of carbons and fluxes of carbons happens mostly in the terrestrial's part. Ratnasingam et al. (2015) highlighted that tropical forest plays a significant role in carbon cycles. Le Quéré et al. (2015) and Malhi et al. (1999) summarized the emission and sink of carbon in the world, and found out that the deforestation caused the carbon emission to doubles its value than it was during the 1980's, while emissions from fossil fuels industry in the last two decades were six times higher. The carbon sink has average of five times increment from the atmospheric growth, land, and ocean. The phenomenon impacts can already be seen through global warming, coral reefs destruction from ocean acidification, and climate change. Therefore, managing forest land cover will contribute in controlling the global carbon fluxes and abate the aftereffect.

Geospatial approach, for instance, Geographic Information System (GIS) and remote sensing (RS) have become one of the most important tools in land management that can consume less cost and time (Geoghegan et al., 2001; Abdullah and Nakagoshi, 2007; Phua et al., 2008; Friehat et al., 2015; Shukri et al., 2018). Certain methods have been introduced in order to evaluate and predict land use and cover (LULC) patterns and trends such as urban growth, agricultural expansion, LULC change, identifying suitable and potential locations for development, and simulating future trends of LULC (Ren et al., 2019).

Moreover, it is quite an issue to find appropriate method and model from abundant of studies for analysing, measuring, assessing, simulating, and predicting deforestation. The main objective of conducting land use forecasting in GIS and RS is to provide support for the decision makers to generate a better or improved sustainable forest management. Most of the studies have make used the RS and GIS environment to detect deforestation (Dong et al., 2012; Kehl et al., 2012; Hamzah et al., 2013), but only few have tried using simulation approach such as CA-Markov hybrid model to provide possible future condition (Vázquez-Quintero et al., 2016). Remote sensing using satellite platform serve a high coverage of the land with good resolution and temporal range. Satellite data such as Landsat, Sentinel, and MODIS are easily accessible and able to provide data for about 185 x 185 km (Landsat), 290 x 290 km (Sentinel) and 2300 x 2300 km (MODIS) area in a single image. Thus, it will able to help in analysing wide area in short time and less cost.

Although there are higher resolution image sources such as from flight platform and drone, but it is expensive and has limited access to the public. The combination of satellite RS and powerful GIS tools can provide low cost, time consuming, and labour forces in land use exploration. For this reason, this study is intended to assess both spatial and temporal distribution in one of the major deforested area in PM, relying on GIS and RS environment.

1.2 Problem Statement

Deforestation in tropical forest region always has the agricultural activity as the main factor for natural forest disturbance (Barbier and Burgess, 2002; Olaniyi et al., 2012). Agricultural expansion happens mostly in the highly agriculture-dependable economics because of the environment suitability, increase of demands, and profitability, resulting in extension of land area to support the needs. The loss of forest land cover is inversely proportional to area covered by oil palm in Southeast Asia country, whereby, the increment of oil palm production is from expansion of planting area through deforestation (Miyamoto et al., 2014). Omar et al., (2016) discussed that an estimated 61 % of carbon emission in PM comes from conversion of forest covers to oil palm plantation in period between years 2010 to 2015. As a major world's oil palm supplier, it is not surprising that Malaysia try to maximised the export amount of oil palm by increasing the area of plantation, however, ending up becoming one of the factors for national forest land reduction. Deforestation can happen in many ways either from human activities and other phenomenon (such as: logging, encroachment, fires, and flood) (Hamzah et al., 2013), therefore, there is a need to accurately detailed out the patterns and trends of deforestation in specific area to support future sustainable forest development planning.

Over the last two decades the forest land covers experienced changes in extent due to development and economic expansion. As in 2016, Pahang is at the second most in terms of production of oil palm yields closely behind Johor and produces the largest timber production in PM (Omar et al, 2018), and at the end, leading in deforestation rate as they have more land to be exploited. Contributing as much as one fourth of total deforestation in Malaysia (between 1990 to 2010), Pahang state has accumulated approximately 0.2 million hectares (mha) of forest area loss with a deforestation rate is estimated to be around 0.02 mha per year (Omar et al., 2018). Study by Othman et al. (2018) using Normalized Difference Vegetation Index (NDVI) analysis and Shevade et al. (2017), revealed that most reduction in forest land cover happened in the southeast part of the state from 2000 to 2015. Most of the forest cover were converted into other land use mainly to agricultural area and few are due to wood log extraction. Hence, we find that it is essential to do monitoring and prediction of the land cover dynamics in the area for better understanding of current situation and upcoming impacts from the continuation.

In addition to that, Malaysia has the second largest area of peat area in Southeast Asia and Pekan district including small part in Rompin district has existence of the largest peat swamp forest in PM (Page et al., 2011; Omar et al., 2018). Miettinen et al. (2011) reported that, Malaysian peat swamp forests experienced clearly a higher deforestation rates at an average annual rate of 2.0 % from 2000 to 2010 compared to 0.9 % for montane or dipterocarp forest. Omar et al. (2016) also concludes that peat swamp degrade greater than any other forest type in Malaysia. The forest type is most likely to be degraded from agriculture activities because of their characteristics, which usually extended on a flat lowland area (Shevade and Loboda, 2019) that favours for human access and encourages rapid development (Butler et al., 2004).

Forest usually covers a vast area and remoted from human settlement that it is difficult to see the changes from horizontal surface view. The existing remote sensing technology make it possible for us to monitor the changes using less cost, time, and labour. There are vast previous studies in monitoring forest land covers exploitation and varies based on the type of data and methods used (Phua et al., 2007; Echeverria et al., 2008; Panta et al., 2009; Dong et al., 2012; Hamzah et al., 2013; Vázquez-Quintero et al., 2016). They are all applicable for forest study and have high method accuracy, yet it depends on the data accessibility and availability, and fund to support the study.

Additionally, the prediction of future land cover in an area is very important process that provides decision makers the rate and direction of changes of the landscape (Khawaldah, 2016). Up until now, there are few models have been widely used in forest loss prediction including the logistic regression (Chowdhury, 2006; Echeverria et al., 2008), genetic algorithms (Venema et al. 2005; Soares-Filho et al. 2013), weights of evidence (Soares-Filho et al. 2010; Maeda et al. 2011) and cellular automata (Thapa et al. 2013). However, there are very few assessments that have solely predicts the magnitude of forest loss in Malaysia despite the country has been acknowledge to be one of the most deforested country in Southeast Asia (Memarian et al., 2012; Rendana et al., 2015; Abdulkareem et al., 2017; Cushman et al. 2017).

Hence, it becomes clear that there is a need for the assessment of deforestation rate and predicting future forest cover patterns that can help in sustainable management.

1.3 Research questions

1. What are the temporal and spatial changes of forest land in Pekan and Rompin in 27 years?
2. What will be the future trends of the deforestation in Pekan and Rompin?

1.4 Research objectives

The essential of this study mainly to assess the deforestation activity and predict the future extent of forest land in Pahang. These could be achieved through meeting the following objectives:

1. To assess the deforestation dynamics in Southeast Pahang using remote sensing
2. To predict the future spatio-temporal deforestation using CA-Markov model for 2025 and 2035

1.5 Significance of study

The monitoring of forest exploitation is limited is this country. Some existing literature might be too general, which is covering a large area (Koh et al., 2011; Hamid and Abd Rahman, 2016), or too specific, by means of focusing only a small part of a forest region (Hamzah et al., 2013). This study helps to intensify the understanding on deforestation in tropical forest such as at Pekan and Rompin districts from the land use historical assessment (Peh et al., 2011). Besides, the RS and GIS application from this study can assess the effectiveness of forest management and aids with jurisdictions for state forest department to improvise the current practices. The analysis on distance to large population centre, protected area, elevation, and slope of the deforested land will add in understanding the forest alteration factors. The factors for forest land cover alteration are varies (e.g: agriculture, elevation, slope soil, population), therefore, every region will have their own factors that affect the forest resources exploitation. This study will analyse deforestation dynamics in the study area by elucidating the effective factors that may contribute to the deforestation activity. Furthermore, this study will provide future output and trend of forest land reduction. The trend and pattern of land change able to show how severe the land can be affected if we continue to exploit the resources based on the historical rate. Overall, this study can prove the benefits of using modern comprehensive technique in helping to assess a large hardly-accessible area historically and spatially using remote sensing.

1.6 Research scope and limitations

This research is based on a series of different spatial, temporal, and quantitative techniques within remote sensing and GIS-based environment. The scope of the research described in this proposition is limited as follows. First, this study is conducted on three group of time series in 10 years of interval for the first and second, and 7 years for the third series. The forest land cover monitoring is periodical, therefore there is less data availability for validation process. As an addition, half of the forest region in the study area are covered with protected forest region including lowland dipterocarp and peat swamp forest type. The status of forest, either protected or state land, put the forest land under different pressure of deforestation due to how it is managed. Other than that, this study determines only four land use categories including forest, non-forest vegetation, openland and built-up, and waterbodies, and the land use will be determined in the period between 1990 to 2017 in Pekan and Rompin districts to explain the historical deforestation patterns. Forest can be differentiated from other vegetation based on their characteristics which are dense green, rough and usually covers large area, while other vegetation such as secondary forests, crops, and grassland appears similarly as light green vegetation. The study focuses on analysing the changes mainly for forest land, so other vegetation were grouped together for that it can reduce misinterpretation and provide a better differentiation of forest land cover. Besides, forest land cover reduction can be contributed from varies of drivers specific for each forest region, thus it will be more complex for us to really understand what are driving the deprivation of the natural ecosystem if the study area is too large. Therefore, it is important to limits the area of study focusing on localized forest land to ensure that we can identify the significance contributing factors.

1.7 Thesis outline

This thesis emphasizes five main chapters in order to provide better understanding and explanation on how the study was conducted and the priority set to it;

Chapter 1 marks out the introduction where the background of study is being described in details which include statement of the problem, research questions and objectives, significance of study, and research scope and limitations.

Chapter 2 focuses on the literature review, which is the general of remote sensing in forest management and characteristics of land use model approaches adopted in the design of theoretical framework of research study.

Chapter 3 explain the study area, and materials and methods used. It explains on how the study was organized and conducted.

Chapter 4 present the results and discussion summarized in text, tables, and figures from data acquired throughout the entire analyses.

Chapter 5 conclude all the important data and findings, and specify suggestion for future work proposed concerning the research study.

REFERENCES

Abdullah, S. A., & Nakagoshi, N. (2007). Forest fragmentation and its correlation to human land use change in the state of Selangor, peninsular Malaysia. *Forest Ecology and Management*, *241*, 39–48.

Agarwal, D. K., Silander Jr, J. A., Gelfand, A. E., Dewar, R. E., & Mickelson Jr, J. G. (2005). Tropical deforestation in Madagascar: analysis using hierarchical, spatially explicit, Bayesian regression models. *Ecological modelling*, 185(1), 105-131.

Alqurashi, A. F., Kumar, L., & Sinha, P. (2016). Urban Land Cover Change Modelling Using Time-Series Satellite Images: A Case Study of Urban Growth in Five Cities of Saudi Arabia. *Remote Sensing*, *8*, 838.

Anees, M. T., Abdullah, K., Nawawi, M. N. M., Nik Ab Rahman, N. N., Mt. Piah, A. R., Syakir, M. I., & Mohd Omar, A. K. (2017). Effect of upstream on downstream due to spatio-temporal land use land cover changes in Kelantan, Peninsular Malaysia. *Nature Environment and Pollution Technology*, *16*(1).

Arekhi, S., & Jafarzadeh, A. A. (2014). Forecasting areas vulnerable to forest conversion using artificial neural network and GIS (case study: Northern Ilam forests, Ilam province, Iran). *Arabian Journal of Geosciences*, *7*(3), 1073–1085.

Ashraf, J., Pandey, R., & de Jong, W. (2017). Assessment of bio-physical, social and economic drivers for forest transition in Asia-Pacific region. *Forest Policy and Economics*, *76*, 35–44.

Asokan, A., & Anitha, J. (2019). Change detection techniques for remote sensing applications: a survey. *Earth Science Informatics,* 12(2), 143-160.

Balser, A. W., & Wylie, B. K. (2010). Multitemporal L-and C-band synthetic aperture radar to highlight differences in water status among boreal forest and wetland systems in the Yukon Flats, interior Alaska (No. 2010-1027). *US Geological Survey*.

Barbier, E. B., & Burgess, J. C. (2002). The Economics of Tropical Deforestation. *Journal of Economic Surveys*, *15*(3), 413–433.

Barrow, C. J., Clifton, J., Chan, N. W., & Tan, T. L. (2005). Sustainable development in the Cameron Highlands, Malaysia. *Malaysian Journal of Environmental Management*, *6*, 41–57.

Batty, M., & Xie, Y. (1994). Modelling inside GIS: Part 2. Selecting and calibrating urban models using ARC-INFO. *International Journal of Geographical Information Systems*, 8(5), 451-470.

Batty, M., Xie, Y., & Sun, Z. (1999). Modeling urban dynamics through GIS-based cellular automata. *Computers, environment and urban systems*, 23(3), 205-233.

Benatti, J. H., & Rodrigues, L. (2005). Privately-owned forests and deforestation reduction: an overview of policy and legal issues. In P. Moutinho & S. Schwartzman (Eds.), *Tropical Deforestation and Climate Change*, 111–117.

Brookfield, H., & Byron, Y. (1990). Deforestation and timber extraction in Borneo and the Malay Peninsula. The record since 1965. *Global Environmental Change*, *1*(1), 42–56.

Bruijnzeel, L. A. (2004). Hydrological functions of tropical forests: Not seeing the soil for the trees? In *Agriculture, Ecosystems and Environment* (Vol. 104).

Butler, B. J., Swenson, J. J., & Alig, R. J. (2004). Forest fragmentation in the Pacific Northwest: Quantification and correlations. *Forest Ecology and Management*, *189*(1–3), 363–373.

Cabral, P., & Zamyatin, A. (2006). Three Land Change Models for Urban Dynamics Analysis in Sintra-Cascais Area. *Proceedings of First Workshop of the EARSEL SIG on Urban Remote Sensing: Challenges and Solutions*, (March).

Cabral, P., & Zamyatin, A. (2009). Markov processes in modeling land use and land cover changes in Sintra-Cascais, Portugal. *Dyna*, 76(158), 191-198.

Carr, D, L. (2004). Proximate Population Factors and Deforestation in Tropical Agricultural Frontiers. *Population and Environment*, *25*(6), 585–612.

Carwardine, J., Wilson, K. A., Ceballos, G., Ehrlich, P. R., Naidoo, R., Iwamura, T., ... & Possingham, H. P. (2008). Cost-effective priorities for global mammal conservation. *Proceedings of the National Academy of Sciences*, 105(32), 11446-11450.

Chang-Martínez, L., Mas, J.-F., Valle, N., Torres, P., & Folan, W. (2015). Modeling Historical Land Cover and Land Use: A Review fromContemporary Modeling. *ISPRS International Journal of Geo-Information*, *4*(4), 1791–1812.

Chape, S., Harrison, J., Spalding, M., & Lysenko, I. (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360(1454), 443-455.

Cheng, Y., Yu, L., Cracknell, A. P., & Gong, P. (2016). Oil palm mapping using Landsat and PALSAR: a case study in Malaysia. *International Journal of Remote Sensing*, *37*(22), 5431–5442.

Chowdhury, R. R. (2006). Driving forces of tropical deforestation: The role of remote sensing and spatial models. *Singapore Journal of Tropical Geography*, 27(1), 82-101.

Clarke, K. C. (1998). Loose-coupling a cellular automaton model and GIS: long-term urban growth prediction for San Francisco and Washington/Baltimore. *International Journal of GIS*, 12, 17 pp. 699–714.

Clarke, K. C., & Gaydos, L. J. (1998). Loose-coupling a cellular automaton model and GIS: long-term urban growth prediction for San Francisco and Washington/Baltimore. *International journal of geographical information science*, 12(7), 699-714.

Clarke, K.C., Hoppen, S. and Gaydos, L.J. (1996). A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area. *Environment and Planning B*, 24: pp. 247–261

Collins, L. (1975). An introduction to Markov chain analysis. *Geo Abstracts Ltd*. Retrieved from https://alexsingleton.files.wordpress.com/2014/09/1-intro-markov-chain-analysis.pdf

Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote sensing of environment,* 37(1), 35-46.

Cushman, S. A., Macdonald, E. A., Landguth, E. L., Malhi, Y., & Macdonald, D. W. (2017). Multiple-scale prediction of forest loss risk across Borneo. *Landscape ecology*, 32(8), 1581-1598.

Darmawan, M., Aniya, M., & Tsuyuki, S. (2001). Forest Fire Hazard Model Using Remote Sensing and Geographic Information Systems: Toward understanding of Land and Forest Degradation in Lowland areas of East Kalimantan, Indonesia, *22nd Asian Conference on Remote Sensing*, 5-9 November 2001, Singapore (unpublished)

Department of Irrigation and Drainage (DID). 2009. Annual Flooding Report of Pahang State 2008/2009. *Department of Irrigation and Drainage Malaysia*.

Dohong, A., Aziz, A. A., & Dargusch, P. (2017). A review of the drivers of tropical peatland degradation in South-East Asia. *Land Use Policy*, *69*(October), 349–360.

Dong, J., Xiao, X., Sheldon, S., Biradar, C., & Xie, G. (2012). Mapping tropical forests and rubber plantations in complex landscapes by integrating PALSAR and MODIS imagery. *ISPRS Journal of Photogrammetry and Remote Sensing*, *74*, 20–33.

Douglas, I. (1999). Hydrological investigations of forest disturbance and land cover impacts in South-East Asia: a review. *Phil.Trans. R. Soc.*

Lond. B, (354), 1725–1738.

Eastman, J. R. (2003). IDRISI Kilimanjaro: guide to GIS and image processing (p. 305). *Clark Labs, Clark University*, Worcester, MA.

Eastman, J. R. (2006). IDRISI Andes tutorial. *Clark Labs*, Worcester, MA.

Eastman, J. R. (2009). IDRISI Taiga guide to GIS and image processing. *Clark Labs, Clark University*, Worcester, MA.

Eastman, J. R. (2012). IDRISI selva. Clark University, Worcester, MA.

Echeverria, C., Coomes, D. A., Hall, M., & Newton, A. C. (2008). Spatially explicit models to analyze forest loss and fragmentation between 1976 and 2020 in southern Chile. *Ecological Modelling*, *212*(3–4), 439–449.

El Hajj, M., Guillaume, S., Bégué, A., & Martiné, J. F. (2008). Combining multi-source information for crop monitoring. *Proceedings of the 11th International Conference on Information Fusion, FUSION 2008*, 3–9.

Engelen, G., Geertman, S., Smits, P., & Wessels, C. (1999). Dynamic GIS and strategic physical planning support: a practical application. In *Geographical information and planning* (pp. 87-111). Springer, Berlin, Heidelberg.

Erener, A. (2011). Remote sensing of vegetation health for reclaimed areas of Seyitömer open cast coal mine. *International Journal of Coal Geology*, 86(1), 20-26.

FAO. 1988. Interim Assessment 1988. Rome. Retrieved from http://www.fao.org/3/a-s8478e.pdf

FAO. 2001. Global Forest Resources Assessment FRA 2000 – Main report. Rome. Retreived from http://www.fao.org/forestry/fra2000report/en/

FAR. 2010. Forestry Annual Report FAR 2010. Retrieved from https://www.forestry.gov.my/en/component/flippingbook/book/15-laporan-tahunan-2013/4-laporan-tahunan?Itemid=1188

Fathizad, H., Rostami, N., & Faramarzi, M. (2015). Detection and prediction of land cover changes using Markov chain model in semi-arid rangeland in western Iran. *Environmental Monitoring and Assessment*, *187*(10).

FRA. 2010. Global Forest Resources Assessment FRA 2010 - Country Report. Rome. Retrieved from http://www.fao.org/docrep/013/al558E/al558E.pdf

Friehat, T., Mulugeta, G., & Gala, T. S. (2015). Modeling Urban Sprawls in Northeastern Illinois. *Journal of Geosciences and Geomatics*, *3*(5), 133–141.

Gaveau, D. L. A., Locatelli, B., Salim, M. A., Yaen, H., Pacheco, P., & Sheil,

D. (2018). Rise and fall of forest loss and industrial plantations in Borneo (2000–2017). *Conservation Letters*, (June 2018), 1–8.

Geist, H. J., & Lambin, E. F. (2001). What drives tropical deforestation. *LUCC Report series*, 4, 116.

Geist, H. J., & Lambin, E. F. (2002). Proximate Causes and Underlying Driving Forces of Tropical Deforestation. *BioScience*, *52*(2), 143–150.

Geoghegan, J., Villar, S. C., Klepeis, P., Mendoza, P. M. A., Ogneva-Himmelberger, Y., Chowdhury, R. R., … Vance, C. (2001). Modeling tropical deforestation in the southern Yucatán peninsular region: Comparing survey and satellite data. *Agriculture, Ecosystems and Environment*, *85*(1–3), 25–46.

Gibbs, H. K., Brown, S., Niles, J. O., & Foley, J. A. (2007). Monitoring and estimating tropical forest carbon stocks: Making REDD a reality. *Environmental Research Letters*, *2*(4). https://doi.org/10.1088/1748-9326/2/4/045023

Gupta, R. P. (2003). Remote sensing geology. *Springer-Verlag*, Berlin

Hall, C. A. S., Tian, H., Qi, Y., Pontius, G., & Cornell, J. (1995). Modelling Spatial and Temporal Patterns of Tropical Land Use Change. *Journal of Biogeography*, *22*, 753.

Hamdan, O., Abd Rahman, K., Samsudin, M., Omar, H., Kassim, A. R., & Musa, S. (2016). Quantifying rate of deforestation and CO 2 emission in Peninsular Malaysia using Palsar imageries. *IOP Conference Series: Earth and Environmental Science*, *37*(1), 012028.

Hamid, W. A., & Abd Rahman, S. B. W. (2016). Comparison results of forest cover mapping of Peninsular Malaysia using geospatial technology. *IOP Conference Series: Earth and Environmental Science*, *37*(1).

Hamzah, K. A., Idris, A. S., & Parlan, I. (2013). Classification of Degraded Peat Swamp Forest for Restoration Planning at Landscape Level Using Remote Sensing Technique. *Journal of Forest Science*, *29*(1), 49–57.

Haan, C. T. (1977). Statistical methods in hydrology. *The Iowa State University Press*.

Harun, R., Sulong, A., Wai, Y. H., Ismail, T. H., Yusoff, M. K., Abdul Manaf, L., & Juahir, H. (2010). Impacts of Forest Changes on Indigenous People Livelihood in Pekan District, Pahang. *Environment Asia*, *3*, 156–159.

Huang, H., Legarsky, J. J., Gudimetla, S., & Davis, C. H. (2004). Post-classification smoothing of digital classification map of St. Louis, Missouri. In IGARSS 2004. *2004 IEEE International Geoscience and Remote Sensing Symposium*, 5, 3039-3041

Huijnen, V., Wooster, M. J., Kaiser, J. W., Gaveau, D. L. A., Flemming, J., Parrington, M., … Van Weele, M. (2016). Fire carbon emissions over maritime southeast Asia in 2015 largest since 1997. *Scientific Reports*, *6*(February), 1–8.

Iacono, M., Levinson, D., El-Geneidy, A., & Wasfi, R. (2015). A Markov Chain Model of Land Use Change. *Tema. Journal of Land Use, Mobility and Environment*, *8*(3), 263–276.

Imhoff, M., Story, M., Vermillion, C., Khan, F., & Polcyn, F. (1986). Forest Canopy Characterization and Vegetation Penetration Assessment with Space-Borne Radar. *IEEE Transactions on Geoscience and Remote Sensing*, *GE-24*(4), 535–542.

Irwin, E. G., & Geoghegan, J. (2001). Theory, data, methods: developing spatially explicit economic models of land use change. *Agriculture, Ecosystems & Environment*, 85(1-3), 7-24.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change (p. 688). Cambridge, United Kingdom and New York, NY, USA: *Cambridge University Press*.

International Tropical Timber Organization (ITTO), 1992. Criteria for the Measurement of Sustainable Tropical Forest Management. International Tropical Timber Organisation, Yokohama, 5pp.

Islam, M. S., & Ahmed, R. (2011). Land Use Change Prediction In Dhaka City Using GIS Aided Markov Chain Modeling. *Journal of Life and Earth Science*, *6*, 81–89.

Joshi, N., Baumann, M., Ehammer, A., Fensholt, R., Grogan, K., Hostert, P., … Waske, B. (2016). A review of the application of optical and radar remote sensing data fusion to land use mapping and monitoring. *Remote Sensing*, *8*(1),

Jusoff, K., Hassan, C. H., & Khali Aziz, H. (2007). Tropical Peat Swamp Forest Ecosystem and Floristic Diversity in Pahang, Malaysia. *International Journal of Systems Applications, Engineering & Development*, *3*(1), 41–44.

Kehl, T. N., Todt, V., Veronez, M. R., & Cazella, S. C. (2012). Amazon rainforest deforestation daily detection tool using artificial neural networks and satellite images. *Sustainability*, *4*(10), 2566–2573.

Khawaldah, H. A. (2016). A Prediction of Future Land Use / Land Cover in Amman Area Using GIS-Based Markov Model and Remote Sensing. *Journal of Geographic Information System*, (June), 412–427.

Kityuttachai, K., Tripathi, N. K., Tipdecho, T., & Shrestha, R. (2013). CA-

Markov analysis of constrained coastal urban growth modeling: Hua hin Seaside City, Thailand. *Sustainability (Switzerland)*, *5*, 1480–1500.

Koh, L. P., Miettinen, J., Liew, S. C., & Ghazoul, J. (2011). Remotely sensed evidence of tropical peatland conversion to oil palm. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(12), 5127–5132.

Lamb, D., Erskine, P. D., & Parrotta, J. A. (2005). Restoration of degraded tropical forest landscapes. Supporting Online Material. *Science (New York, N.Y.)*, *310*(5754), 1628–1632. https://doi.org/10.1126/science.1111773

Lambin, E. F. (1997). Physical Geography Modelling monitoring land-cover change processes in tropical regions and. *Progress in Physical Geography*, 375–393.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., ... & George, P. (2001). The causes of land-use and land-cover change: moving beyond the myths. *Global environmental change*, 11(4), 261-269.

Landis, J., & Zhang, M. (1998). The second generation of the California urban futures model. Part 2: Specification and calibration results of the land-use change submodel. *Environment and Planning B: Planning and Design*, 25(6), 795-824.

Laurance, W. F. (1999). Reflections on the tropical deforestation crisis. *Biological Conservation*, *91*, 109–117.

Leh, M., Bajwa, S., & Chaubey, I. (2013). Impact of Land Use Change on Erosion Risk: An Integrated Remote Sensing, Geographic Information System and Modeling Methodology. *Land Degradation and Development*, *24*(5), 409–421.

Leblois, A., Damette, O., & Wolfersberger, J. (2017). What has driven deforestation in developing countries since the 2000s? Evidence from new remote-sensing data. *World Development*, 92, 82-102.

Le Quéré, C., Moriarty, R., Andrew, R. M., Canadell, J. G., Sitch, S., Korsbakken, J. I., ... & Houghton, R. A. (2015). Global carbon budget 2015. *Earth System Science Data*, 7(2), 349-396.

Li, T., & Li, W. (2015). Multiple land use change simulation with Monte Carlo approach and CA-ANN model, a case study in Shenzhen, China. *Environmental Systems Research*, 4(1), 1.

Li, X., & Yeh, A. G. O. (2002). Urban simulation using principal components analysis and cellular automata for land-use planning. *Photogrammetric engineering and remote sensing*, 68(4), 341-352.

Lillesand, T. M. & Kiefer, R. W. (1994). Remote Sensing and Image

Intepretation, *John Wiley and Sons. Inc.*, New York.

Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. (2008). Digital image interpretation and analysis. *Remote sensing and image interpretation*, 6, 545-81.

Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). Remote sensing and image interpretation. John Wiley & Sons.

Lopez, E., Bocco, G., Mendoza, M., & Duhau, E. (2001). Predicting land-cover and land-use change in the urban fringe A case in Morelia city , Mexico. *Landscape and Urban Planning*, *55*, 271–285.

Maeda, E. E., De Almeida, C. M., de Carvalho Ximenes, A., Formaggio, A. R., Shimabukuro, Y. E., & Pellikka, P. (2011). Dynamic modeling of forest conversion: Simulation of past and future scenarios of rural activities expansion in the fringes of the Xingu National Park, Brazilian Amazon. *International Journal of Applied Earth Observation and Geoinformation*, 13(3), 435-446.

Malhi, Y., Baldocchi, D. D., & Jarvis, P. G. (1999). The carbon balance of tropical, temperate and boreal forests. *Plant, Cell and Environment*, (22), 715–740.

Malaysian Palm Oil Board (MPOB). 2019. Retrieved from https://www.ceicdata.com/ en/malaysia/planted-area-oil-palm/oil-palm-planted-area-pahang.

Mansor, S., Shariah, M. A., Billa, L., Setiawan, I., & Jabar, F. (2004). Spatial technology for natural risk management. *Disaster Prevention and Management: An International Journal*, *13*(5), 364–373.

Markham, B. L., Storey, J. C., Williams, D. L., & Irons, J. R. (2004). Landsat sensor performance: history and current status. *IEEE Transactions on Geoscience and Remote Sensing*, 42(12), 2691-2694.

Mas, J.-F., Puig, H., Palacio, J. L., & Sosa-López, A. (2004). Modelling deforestation using GIS and artificial neural networks. *Environmental Modelling and Software*, *19*(5), 461–471.

Masum, K. M., Mansor, A., Sah, S. A. M., & Lim, H. S. (2017). Effect of differential forest management on land-use change (LUC) in a tropical hill forest of Malaysia. *Journal of Environmental Management*, *200*, 468–474.

Matricardi, E. A. T., Skole, D. L., Pedlowski, M. A., Chomentowski, W., & Fernandes, L. C. (2010). Assessment of tropical forest degradation by selective logging and fire using Landsat imagery. *Remote Sensing of Environment*, *114*(5), 1117–1129.

Matthews, R. B., Gilbert, N. G., Roach, A., Polhill, J. G., & Gotts, N. M. (2007). Agent-based land-use models: a review of applications.

Landscape Ecology, 22(10), 1447-1459.

Memarian, H., Balasundram, S. K., Talib, J. Bin, Teh, C., Sung, B., Sood, A. M., & Abbaspour, K. (2012). Validation of CA-Markov for Simulation of Land Use and Cover Change in the Langat Basin , Malaysia. *Journal of Geographic Information System*, *4*(December), 542–554.

Meyer, W.B. & Turner B.L. (Eds.), 1994. Changes in Land Use and Land Cover: A Global Perspective. *Cambridge University Press,* Cambridge.

Miettinen, J., Shi, C., & Liew, S. C. (2011). Deforestation rates in insular Southeast Asia between 2000 and 2010. *Global Change Biology*, *17*(7), 2261–2270.

Miettinen, J., Shi, C., & Liew, S. C. (2016). Land cover distribution in the peatlands of Peninsular Malaysia, Sumatra and Borneo in 2015 with changes since 1990. *Global Ecology and Conservation*, *6*, 67–78.

Mirkatouli, J., Hosseini, A., & Neshat, A. (2015). Analysis of land use and land cover spatial pattern based on Markov chains modelling. *City, Territory and Architecture*, *2*, 4.

Mitsova, D., Shuster, W., & Wang, X. (2011). A cellular automata model of land cover change to integrate urban growth with open space conservation. *Landscape and urban planning*, 99(2), 141-153.

Miyamoto, M., Mohd Parid, M., Noor Aini, Z., & Michinaka, T. (2014). Proximate and underlying causes of forest cover change in Peninsular Malaysia. *Forest Policy and Economics*, *44*, 18–25.

Mon, M. S., Mizoue, N., Htun, N. Z., Kajisa, T., & Yoshida, S. (2012). Factors affecting deforestation and forest degradation in selectively logged production forest: A case study in Myanmar. *Forest Ecology and Management*, 267, 190-198.

Muller, M. R., & Middleton, J. (1994). A Markov model of land-use change dynamics in the Niagara Region, Ontario, Canada. *Landscape Ecology*, *9*(2), 151–157.

Mustafa, M. R. U., Sholagberu, A. T., Syazwan, M. A., Yusof, K. W., Hashim, A. M., & Abdurrasheed, A. S. (2019). Land-use assessment and its influence on spatial distribution of rainfall erosivity: Case study of Cameron Highlands Malaysia. *Journal of Ecological Engineering*, *20*(2), 183–190.

Myers, N. (1992). Future operational monitoring of tropical forests: An alert stratergy. *World Forest Watch Conference Proceedings*, Joint Research Centre, Ispra, Italy, 81.

NEPCon. (2016). *Supply Chain Mapping of Malaysian Timber and Wood-based Industries of Malaysian Timber and Wood-based Industries*. Retrieved from http://awsassets.wwf.org.my/downloads/final_supply_chain_mapping_report_18jan16.pdf

Ojima, D. S., Galvin, K. A., & Turner, B. L. (1994). The global impact of land-use change. *BioScience*, 44(5), 300-304.

Olaniyi, A. O., Abdullah, A. M., Ramli, M. F., & Sood, A. M. (2012). Linkage Between Economy, Agricultural Land Use and Forest Processes - A Case Study of Selangor, Malaysia. *International Journal of Sustainable Development*, *3*(9), 21–40.

Omar, H., Misman, M. A., & Kassim, A. R. (2017). Synergetic of PALSAR-2 and Sentinel-1A SAR Polarimetry for Retrieving Aboveground Biomass in Dipterocarp Forest of Malaysia. *Applied Sciences*, *7*(7), 675.

Omar, H., Mohd Johan Chuah, N., Parlan, I., Abu Samah, A. K., & Musa, S. (2015). Assessing carbon pools in dipterocarp forests of Peninsular Malaysia. *Journal of Tropical Resources and Sustainable Science*, *3*, 214–221.

Omar, H., Mohd Johan Chuah, N., Parlan, I., & Musa, S. (2016). Emission of CO2 resulted from conversion of forests to agricultural landuse in malaysia. *International Journal of Agriculture, Forestry and Plantation*, *2*(Ipcc 2007), 192–201.

Omar, H., Mohd Johan Chuah, N., Parlan, I., Musa, S., & Wan Abd Rahman, W. A. H. S. (2018). *Forest Reference Emission Level for REDD+ in Pahang, Malaysia*. Forest Research Institute Malaysia

Othman, M. A., Ash'Aari, Z. H., Aris, A. Z., & Ramli, M. F. (2018). Tropical deforestation monitoring using NDVI from MODIS satellite: A case study in Pahang, Malaysia. *IOP Conference Series: Earth and Environmental Science*, *169*(1).

Ozturk, D. (2015). Urban growth simulation of Atakum (Samsun, Turkey) using cellular automata-Markov chain and Multi-layer Perceptron-Markov chain models. *Remote Sensing*, *7*, 5918–5950.

Page, S. E., Rieley, J. O., & Banks, C. J. (2011). Global and regional importance of the tropical peatland carbon pool. *Global Change Biology*, *17*(2), 798–818.

Pahang Department of Forestry Annual Report, FAR. (2009). Retrieved from http://forestry.pahang.gov.my/index.php/penerbitan/laporan-tahunan

Pahang Department of Forestry Annual Report, FAR. (2010). Retrieved from http://forestry.pahang.gov.my/index.php/penerbitan/laporan-tahunan

Pahang Department of Forestry Annual Report, FAR. (2015). Retrieved from http://forestry.pahang.gov.my/index.php/penerbitan/laporan-tahunan

Pahang Department of Forestry Annual Report, FAR. (2018). Retrieved from http://forestry.pahang.gov.my/index.php/penerbitan/laporan-tahunan

Pakhriazad, H.-Z., & Takeo, S. (2004). A Study in Timber and Wood-Based Industries Development in the State of Pahang , Peninsular. *Journal of Forest Economics*, *50*(1), 76–82.

Panta, M., Kim, K., & Joshi, C. (2009). Temporal mapping of deforestation and forest degradation in Nepal: Applications to forest conservation. *Forest Ecology and Management*, *256*(9), 1587–1595.

Parker, D. C., Manson, S. M., Janssen, M. A., Hoffmann, M. J., & Deadman, P. (2003). Multi-agent systems for the simulation of land-use and land-cover change: a review. *Annals of the association of American Geographers*, 93(2), 314-337.

Parzen, E. (1962). On estimation of a probability density function and mode. *The annals of mathematical statistics*, 33(3), 1065-1076.

Peh, K. S.-H., Soh, M. C. K., Sodhi, N. S., Laurance, W. F., Ong, D. J., & Clements, R. (2011). Up in the Clouds: Is Sustainable Use of Tropical Montane Cloud Forests Possible in Malaysia? *BioScience*, *61*(1), 27–38.

Pérez-Vega, A., Mas, J. F., & Ligmann-Zielinska, A. (2012). Comparing two approaches to land use/cover change modeling and their implications for the assessment of biodiversity loss in a deciduous tropical forest. *Environmental Modelling & Software*, 29(1), 11-23.

Phillips, V. D. (1998). Peatswamp ecology and sustainable development in Borneo. *Biodiveristy and Conservation*, *7*, 651–671.

Phua, M. H., & Minowa, M. (2005). A GIS-based multi-criteria decision making approach to forest conservation planning at a landscape scale: A case study in the Kinabalu Area, Sabah, Malaysia. *Landscape and Urban Planning*, *71*, 207–222.

Phua, M. H., Tsuyuki, S., Furuya, N., & Lee, J. S. (2008). Detecting deforestation with a spectral change detection approach using multitemporal Landsat data: A case study of Kinabalu Park, Sabah, Malaysia. *Journal of Environmental Management*, *88*(4), 784–795.

Phua, M. H., Tsuyuki, S., Lee, J. S., & Sasakawa, H. (2007). Detection of burned peat swamp forest in a heterogeneous tropical landscape: A case study of the Klias Peninsula, Sabah, Malaysia. *Landscape and Urban Planning*, *82*, 103–116.

Pinder, J. E., Rea, T. E., & Funsch, D. E. (1999). Deforestation, Reforestation and Forest Fragmentation on the Upper Coastal Plain of South Carolina and Georgia. *The American Midland Naturalist*, *142*(2), 213–228.

Pontius Jr., R. G., Cornell, J. D., & Hall, C. A. S. (2001). Modeling the spatial pattern of land-use change with GEOMOD2: Application and validation for Costa Rica. *Agriculture, Ecosystems and Environment*, *85*(1–3), 191–203.

Pontius Jr., R. G., & Malanson, J. (2005). Comparison of the structure and accuracy of two land change models. *International Journal of Geographical Information Science*, *19*(August 2016), 745–748.

Pontius Jr., R. G., Malanson, J., Pontius, G. R., Malanson, J., Pontius Jr., R. G., & Malanson, J. (2005). Comparison of the structure and accuracy of two land change models. *International Journal of Geographical Information Science*, *19*(2), 243–265.

Pontius, R. G., Huffaker, D., & Denman, K. (2004). Useful techniques of validation for spatially explicit land-change models. *Ecological Modelling*, *179*(4), 445–461.

Rashmi, M. K., & Lele, N. (2010). Spatial modeling and validation of forest cover change in Kanakapura region using GEOMOD. *Journal of the Indian Society of Remote Sensing*, *38*(1), 45–54.

Ratnasingam, J., Ramasamy, G., Toong, W., Ioras, F., Canja, C. M., Lupu, M. I., & Abrudan, I. V. (2015). Carbon stocking in the natural forests - The case of Malaysia. *Not Bot Horti Agrobo*, *43*(1), 278–286.

Razali, A., Ismail, S. N. S., Awang, S., Praveena, S. M., & Abidin, E. Z. (2018). Land use change in highland area and its impact on river water quality: a review of case studies in Malaysia. *Ecological processes*, 7(1), 19.

Rees, W. G. (2013). Physical principles of remote sensing. *Cambridge University Press*.

Ren, Y., Lü, Y., Comber, A., Fu, B., Harris, P., & Wu, L. (2019). Spatially explicit simulation of land use/land cover changes: Current coverage and future prospects. *Earth-Science Reviews*, *190*, 398–415.

Rendana, M., Abdul Rahim, S., Idris, W. M. R., Lihan, T., & Ali Rahman, Z. (2015). CA-Markov for Predicting Land Use Changes in Tropical Catchment Area: A Case Study in Cameron Highland, Malaysia. *Journal of Applied Science*, *15*(4), 689–695.

Richards, J. A., & Jia, X. (1999). Remote Sensing Digital Image Analysis. In *Remote Sensing Digital Image Analysis*.

Roy, D. P., Wulder, M. A., Loveland, T. R., Woodcock, C. E., Allen, R. G., Anderson, M. C., & Scambos, T. A. (2014). Landsat-8: Science and product vision for terrestrial global change research. *Remote Sensing of Environment*, 145, 154172.

Saner, P., Loh, Y. Y., Ong, R. C., & Hector, A. (2012). Carbon stocks and fluxes in tropical lowland dipterocarp rainforests in Sabah, Malaysian Borneo. *PLoS ONE*, *7*(1).

Sang, L., Zhang, C., Yang, J., Zhu, D., & Yun, W. (2011). Simulation of land use spatial pattern of towns and villages based on CA–Markov model. *Mathematical and Computer Modelling*, 54(3), 938-943.

Sayer, J. a., & Whitmore, T. C. (1991). Tropical moist forests: Destruction and species extinction. *Biological Conservation*, *55*, 199–213.

Setiawan, I., Mahmud, A. R., Mansor, S., Mohamed Shariff, A. R., & Nuruddin, A. A. (2004). GIS-grid-based and multi-criteria analysis for identifying and mapping peat swamp forest fire hazard in Pahang, Malaysia. *Disaster Prevention and Management: An International Journal*, *13*(5), 379–386.

Shevade, V. S., & Loboda, T. V. (2019). Oil palm plantations in Peninsular Malaysia: Determinants and constraints on expansion. *PLoS ONE*, *14*(2).

Shevade, V. S., Potapov, P. V., Harris, N. L., & Loboda, T. V. (2017). Expansion of Industrial Plantations Continues to Threaten Malayan Tiger Habitat. *Remote Sensing*, *9*(7), 747.

Shimabukuro, Y. E., Arai, E., Duarte, V., Jorge, A., Santos, E. G. D., Gasparini, K. A. C., & Dutra, A. C. (2019). Monitoring deforestation and forest degradation using multi-temporal fraction images derived from Landsat sensor data in the Brazilian Amazon. *International journal of remote sensing*, 40(14), 5475-5496.

Shukri, W. A. H., Osman, R., Haqeem, A., Ibrahim, I., & Sood, A. M. (2018). Assessing success of forest selective management system using geospatial technology. *IOP Conference Series: Earth and Environmental Science*, *169*(1).

Soares-Filho, B., Moutinho, P., Nepstad, D., Anderson, A., Rodrigues, H., Garcia, R., ... & Silvestrini, R. (2010). Role of Brazilian Amazon protected areas in climate change mitigation. *Proceedings of the National Academy of Sciences*, 107(24), 10821-10826.

Soares-Filho, B., Rodrigues, H., & Follador, M. (2013). A hybrid analytical-heuristic method for calibrating land-use change models. *Environmental Modelling & Software*, 43, 80-87.

Soh, M. C., Sodhi, N. S., & Lim, S. L. (2006). High sensitivity of montane bird communities to habitat disturbance in Peninsular Malaysia. *Biological conservation*, 129(2), 149-166.

Stehman, S. V., & Czaplewski, R. L. (1998). Design and analysis for thematic map accuracy assessment: fundamental principles. *Remote sensing of environment*, 64(3), 331-344.

Stewart, W. J. (1994). Introduction to the numerical solution of Markov chains. *Princeton University Press*.

Suarez-Rubio, M., Lookingbill, T. R., & Wainger, L. A. (2012). Modeling exurban development near Washington, DC, USA: comparison of a pattern-based model and a spatially-explicit econometric model. *Landscape Ecology*, 27(7), 1045-1061.

Subedi, P., Subedi, K., & Thapa, B. (2013). Application of a Hybrid Cellular Automaton – Markov (CA-Markov) Model in Land-Use Change Prediction: A Case Study of Saddle Creek Drainage Basin, Florida. *Applied Ecology and Environmental Sciences*, *1*(6), 126–132.

Tan, K. C., Lim, H. S., MatJafri, M. Z., & Abdullah, K. (2010). Landsat data to evaluate urban expansion and determine land use/land cover changes in Penang Island, Malaysia. *Environmental Earth Sciences*, *60*(7), 1509–1521.

Thapa, R. B., Shimada, M., Watanabe, M., Motohka, T., & Shiraishi, T. (2013). The tropical forest in south east Asia: Monitoring and scenario modeling using synthetic aperture radar data. *Applied Geography*, 41, 168-178.

Tonks, A. J., Aplin, P., Beriro, D. J., Cooper, H., Evers, S., Vane, C. H., & Sjögersten, S. (2017). Impacts of conversion of tropical peat swamp forest to oil palm plantation on peat organic chemistry, physical properties and carbon stocks. *Geoderma*, *289*, 36–45.

Torrens, P. M. (2003). Automata-based models of urban systems. *Advanced Spatial Analysis: The CASA Book of GIS*, 61–81.

Turner, B. L., & Meyer, W. B. (1994). Global land-use and land-cover change: an overview. *Changes in land use and land cover: a global perspective*, 4(3).

United Nation Development Programme (UNDP). 2006. Malaysia's Peat Swamp Forets: Conservation and Sustainable Use. In *International Journal of Integrated Engineering – Special Issue on ICONCEES* (Vol. 3). Malaysia: United Nations Development Programme.

United Nations Framework Convention on Climate Change (UNFCCC). 2001. Definitions, Modalities, Rules and Guidelines Relating to LULUCF Activities under the Kyoto Protocol.

Van Noordwijk, M., Tanika, L., & Lusiana, B. (2017). Flood risk reduction and flow buffering as ecosystem services - Part 2: Land use and rainfall intensity effects in Southeast Asia. *Hydrology and Earth System Sciences*, *21*(5), 2341–2360.

Vázquez-Quintero, G., Solís-Moreno, R., Pompa-García, M., Villarreal-Guerrero, F., Pinedo-Alvarez, C., & Pinedo-Alvarez, A. (2016). Detection and projection of forest changes by using the Markov Chain model and cellular automata. *Sustainability (Switzerland)*, *8*(3), 1–13.

Venema, H. D., Calamai, P. H., & Fieguth, P. (2005). Forest structure optimization using evolutionary programming and landscape ecology metrics. *European Journal of Operational Research*, 164(2), 423-439.

Verburg, P. H., De Koning, G. H. J., Kok, K., Veldkamp, A., & Bouma, J. (1999). A spatial explicit allocation procedure for modelling the pattern of land use change based upon actual land use. *Ecological modelling*, 116(1), 45-61.

Verburg, P. H., de Nijs, T. C. M., van Eck, J. R., Visser, H., & de Jong, K. (2004). A method to analyse neighbourhood characteristics of land use patterns. *Computers, Environment and Urban Systems*, *28*, 667–690.

Vieilledent, G., Grinand, C., & Vaudry, R. (2013). Forecasting deforestation and carbon emissions in tropical developing countries facing demographic expansion: a case study in Madagascar. *Ecology and evolution*, 3(6), 1702-1716.

Wainger, L. A., Rayburn, J., & Price, E. W. (2007). Review of land use change models: applicability to projections of future energy demand in the Southeast United States. *Southeast Energy Futures Project Cambridge*, 53, 1-5.

Wang, W. C. (1986). Electromagnetic wave theory. Wiley, New York.

Weng, Q. (2001). A remote sensing? GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. *International journal of remote sensing*, 22(10), 1999-2014.

White, R., & Engelen, G. (1993). Cellular automata and fractal urban form: a cellular modelling approach to the evolution of urban land-use patterns. *Environment and planning A*, 25(8), 1175-1199.

Wolfram, S. (1984). Cellular automata as models of complexity. *Nature*, 311(5985), 419.

Wood, E. C., J. E. Lewis, G. G. Tappan, and R. W. Lietzow (1997), The development of a land cover change model for southern Senegal, presented at Land Use Modeling Workshop, EROS Data Center, Sioux Falls, S.Dak., June 5 – 6.

Wu, F. (2002). Calibration of stochastic cellular automata: the application to rural-urban land conversions. *International Journal of Geographical Information Science*, 16(8), 795-818.

Wu, F., & Webster, C. J. (1998). Simulation of land development through the integration of cellular automata and multicriteria evaluation.