Pertanika J. Soc. Sci. & Hum. 24 (2): 795 – 810 (2016)

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

Modelling Developed Land in Phuket Province of Thailand: 2000-2009

Chuangchang, P.[1], Sangkhaduang, T.[2] and Tongkumchum, P.[1]*

[1]*Department of Mathematics and Computer Science, Faculty of Science and Technology, Prince of Songkla University, Pattani, 94000 Thailand*
[2]*College of Hospitality and Tourism, Rajamangala University of Technology Srivijaya, Trang Campus, 92150 Thailand*

ABSTRACT

The objective of this study is to model land development in the 17 sub-districts in Phuket province of Thailand from 2000 to 2009. Logistic regression was used to monitor changes in land-use over this period and predict future changes. The ROC curve was used to measure the performance of the model. Land-use from a previous survey in 2000 and sub-district identity were included as determinants. The area of developed land increased by 4557 ha over the study period. In 2000, agricultural land was more likely to become developed in 2009 and developed land was more likely to remain developed land in 2009. Land development occurred mostly in Chalong and Talat Nua sub-districts. The area under the ROC curve was 0.83, indicating a reasonably good fit of the model. Prediction of such changes may be used to provide useful information for decision makers and planners.

Keywords: Developed land, urban growth, logistic regression model, land-use data

INTRODUCTION

Urban growth and land development lead to land-use changes in many areas around the world, especially in developing countries, where urbanisation rates are high, impacting on the environment, social structure and economy of the region. Recent studies have shown that urbanised land tends to replace either agricultural land (Lopez *et al.*, 2001; Helmer, 2004; Huang *et al.*, 2009; Belal & Moghanm, 2011; Forkuor & Cofie, 2011; Mohan *et al.*, 2011; Alsaaideh *et al.*, 2012; Alsharif & Pradhan, 2014) or forest land (Thomlinson & Rivera, 2000; Schneider & Pontius, 2001).

ARTICLE INFO

Article history:
Received: 12 March 2015
Accepted: 11 June 2015

E-mail addresses:
tphattra@bunga.pn.psu.ac.th (Tongkumchum, P.),
potjamastan@gmail.com (Chuangchang, P.),
L.caresaad@gmail.com (Sangkhaduang, T.)
* Corresponding author

ISSN: 0128-7702

Statistical models of land-use change and urban growth have become important tools for city planners, economists, ecologists and resource managers, facilitating timely and effective actions for sustainable development of urban regions (Herold *et al.*, 2001). These models can provide insights into the dynamics of the urbanisation system and can be used to forecast future development trends. Different modelling approaches have been adopted in studies of land-use changes from the perspective of their utility to predict changes in land-use intensification (Lambin *et al.*, 2000). Logistic regression has been widely used to model urban growth (Allen & Lu, 2003; Cheng & Masser, 2003; Hu & Lo, 2007; Nong & Du, 2011; Eyoh *et al*., 2012; Alsharif & Pradhan, 2014; Tayyebi *et al*., 2014). However, these studies do not have predictors comprising land-use type in a previous year and spatial correlation, which cause violation of the assumption of independent errors and are difficult to handle (Hu & Lo 2007). The method used to correct for such correlation is largely new and extends further the "variance inflation factor" method recently developed by Thinnukool *et al*. (2014) and Chuangchang and Tongkumchum (2014).

Although land-use change has been extensively studied in Thailand (see, for example, Muttitanon & Tripathi, 2005; Prabnarong & Thongkao, 2006; Swangjang & Iamaram, 2011; Thinnukool *et al.*, 2014), a few empirical studies have focused on urban growth. A basic reason for this lack of research is inconsistencies in data structure which further complicate appropriate model creation. Urban growth is one of the most important types of land-use change currently affecting Thailand, particularly in the south where tourism has grown in Phuket, now attracting more than 5 *million visitors each year.* Tourism is now one of the fastest growing economic sectors in the province. The Phuket Provincial Administration Organisation has implemented a tourism development plan to increase tourism and promote Phuket as a world-class centre of marine tourism, which in turn, generates substantial revenues locally and nationally (Sakolnakorn *et al.*, 2013). Tourism has both positive and negative impacts on the economic and social health of a region. The city area has grown with little consideration to the land-use types that are being transformed. Moreover, poorly managed developmental activities lead to environmental damages. Thus, controlling urbanisation and creating sustainable development require accurate information about urban growth patterns (Jiang & Yao, 2010). A few studies on land-use in Phuket have been published (Ratanasermpong *et al*., 1995; Boupun & Wongsai, 2012). Such historical data also contain valuable information about Phuket's history and culture development that is not available elsewhere, and which is also valuable to planners and developers alike.

The objectives of this study are to detect and evaluate land-use changes, and identify the pattern of changes in developed lands that occurred in Phuket province from 2000 to 2009.

MATERIAL AND METHODS

Study Area

Phuket is the largest island in Thailand. It is located around latitude 7º 53'N and longitude 98º 24'E. Phuket Province is divided into three districts, which are further subdivided into 17 sub-districts (see Fig.1). Mueang Phuket is the capital district of Phuket Province. This district encompasses the southern part of Phuket Island. It is subdivided into eight sub-districts (Koh Keao, Rasada, Wichit, Chalong, Karon, Rawai, Talad Yai and Talad Nuea). Kathu district is located in the west of Phuket Island. Neighbouring Thalang to the north, Mueang Phuket to the east and south, and the Andaman Sea to the west, Kathu also covers the famous tourist beach of Phuket, i.e. Patong. It is subdivided into three sub-districts (Kamala, Kathu and Patong). Thalang, which is the district in the north of Phuket Province, is subdivided into six sub-districts (Thep Krasatti, Si Sunthon, Choeng Thale, Pa Khlok, Mai Khao and Sakhu).

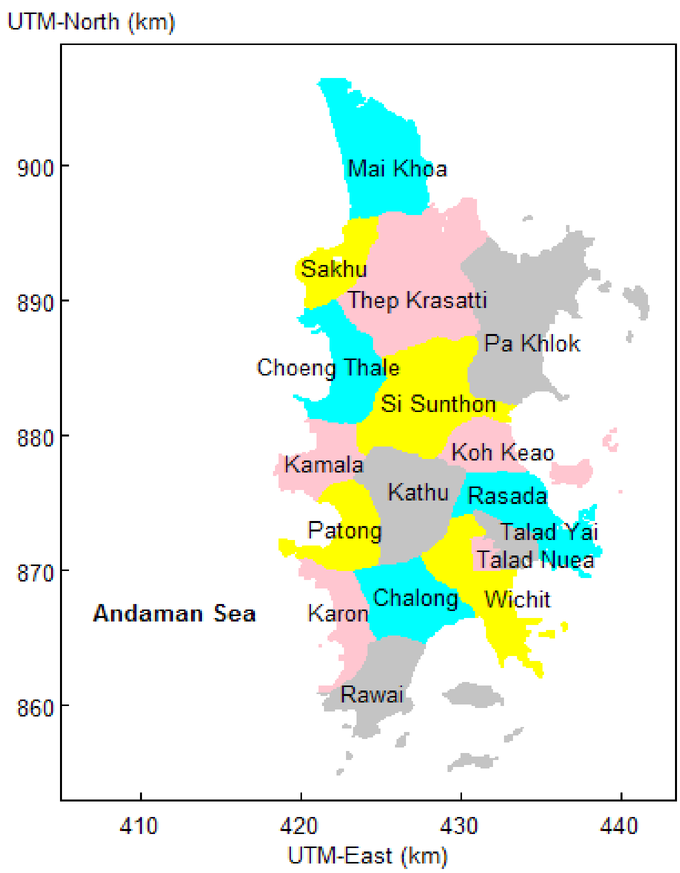

Fig.1: Sub-districts of Phuket province.

The major types of land-use in 2000 included developed lands, undeveloped lands (forest, grassland, water bodies, marsh and swamp), rubber plantations, and agricultural lands (Fig.2).

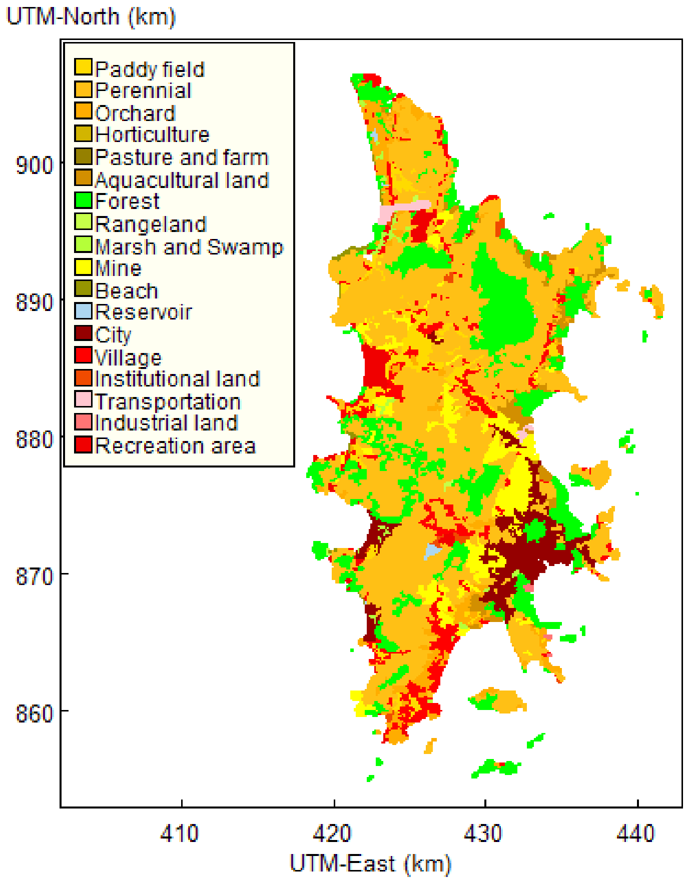

Fig.2: A land-use thematic map of the study area in Phuket province (2000).

Data Management

This study presents an analysis of land-use change for time periods based on a grid-digitised method. Land-use data stored in the analogue (vector or polygonal) form were obtained from the Thailand Department of Land Development for the years 2000 and 2009. Since polygonal land-use data are difficult to analyse because they change in shape and size when land-use changes over time, the data structure can be improved by conversion to data on a fixed grid. This analogue-to-digital conversion method is explained by Thinnukool *et al*. (2014), and uses the function *point.in.polygon* in the spatial (sp) library of the R programme (Pebesma *et al*., 2014). Duplicated polygons arise when larger polygonal land-use plots contain smaller plots such as farm ponds. The data management steps used in this study are summarised in Fig.3.

Land-use data were thus transformed to Universal Transverse Mercator (UTM) coordinates and all land-use coordinates were converted to be consistent with corresponding current Google Earth coordinates. Each grid point corresponds to one-hectare area because each grid represents 100×100 meters.

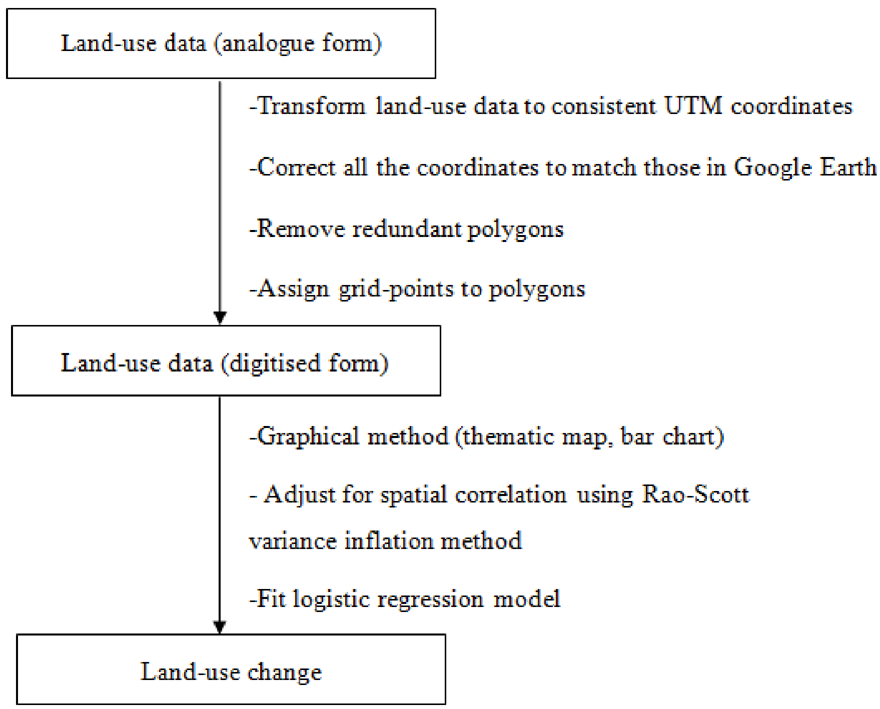

Fig.3: Steps of data management and analysis in this study.

Land-use Categories

The land-use categories were classified into four main groups comprising undeveloped land (UD), rubber plantation (RF), other agriculture (OA) and developed land (Dev). Descriptions of these categories are listed in Table 1.

TABLE 1
Land-Use Classification

Land-use category	Descriptions
Undeveloped land (UD)	Forest, grassland, water bodies, marsh and swamp and miscellaneous land
Rubber plantation (RP)	Rubber plantation
Other agriculture (OA)	Paddy field, field crop perennial, orchard, horticulture, pasture and aquatic plant
Developed land (Dev)	City, town, commercial, village, institutional land, transportation, communication and industrial land

Logistic Regression Model

Logistic regression is a powerful empirical method appropriate to model data where the outcome is binary (Hosmer & Lamshow, 2004). In this study, the land-use data were analysed using this particular method because the outcome at each grid-point is binary. The outcome is developed land coded as 1 (Dev) and 0 (OA). Two factors were considered as determinants of developed lands, namely, sub-district identity and land-use in 2000.

Two logistic probability models were developed to predict the probability of changes in land-use to developed lands from 2000 to 2009. The simpler model included only one factor, while the full model included two factors. The model formulates the logit of the probability p_{ij} of developed lands (Dev) in terms of the two determinant factors, as follows:

$$\log\left[\frac{p_{ij}}{1-p_{ij}}\right] = \mu + \alpha_i + \beta_j$$

In this model, μ is a constant and the terms α_i and β_j refer to land-use group in 2000 and sub-district identity, respectively. Land-use group in 2000 has four levels (see Table 1) and the sub-district factor has 17 levels, with one for each sub-district (see Fig.1).

Variance inflation factors (VIF) were computed to account for the spatial correlation between land-use outcomes within sub-districts and thus provide valid confidence intervals, as described by Rao and Scott (1992). The adjusted percentages of developed lands for each determinant can thus be presented graphically to show confidence intervals. The conventional treatment contrasts method gives different estimates, depending on which level in the factor is selected as the reference group, and it gives wider confidence intervals when this reference group has smaller sample size. To compare sub-district and land-use group effects with their overall mean, rather than with an arbitrary sub-district, the standard errors for the estimated parameters in the model were based on weighted sum contrasts, as described by Tongkumchum and McNeil (2009). An advantage of this method is that it provides a simple criterion for classifying levels of a factor (Kongchouy & Sampantarak, 2010; Chutinantakul *et al.*, 2014). Using this method, the confidence intervals for proportions derived from this method may be classified into three levels: (1) above the mean, (2) crossing the mean, and (3) totally below the mean.

A receiver operating characteristic (ROC) curve describes how well a model predicts a binary outcome. This is a plot of the true positive rate (sensitivity) against the false positive rate (1–specificity) for different possible thresholds of the model. This graph displays the predictive accuracy of the logistic model, which can be evaluated using the area under the ROC curve (AUC). The AUC is particularly important for evaluating how well the method can discriminate between the outcome values. An ideal model would have an AUC of 1. Denoting the predicted outcome as 1 (developed land) if $P_{ij} \geq c$ or 0 (other) if $P_{ij} < c$, the ROC curve plots the proportion of positive outcomes correctly predicted by the model against the false positive rate (proportion of all outcomes incorrectly predicted) as c varies. Choosing c to match the numbers of predicted and observed outcomes ensures that equal weights are assigned to false positive and false negative prediction errors. The AUC measures the performance of a model and can be used as a measurement of model accuracy (Takahashi *et al*., 2006; Sakar & Midi, 2010). It shows how well a model predicts a binary outcome (Fan *et al*., 2006), which varies from 0.5 to 1. An AUC close to 1 signifies that the model has an almost perfect discrimination, while an AUC close to 0.5 indicates a poor discrimination (Hanley & McNeil, 1982).

RESULTS

Land-use Changes in Phuket Province

The bar chart in Fig.4 shows the area (ha) of land-use categories in Phuket province from 2000 and 2009. Most lands were used for rubber plantation, with an area of 25250 ha in 2000 and 19791 ha in 2009. Both developed and undeveloped land areas have been increasing, with areas of 7834 ha in 2000, 12391 ha in 2009, 13280 ha in 2000 and 16152 ha in 2009, respectively. Other agriculture land areas have been decreasing with an area of 5307 ha in 2000 and 3337 ha in 2009, respectively.

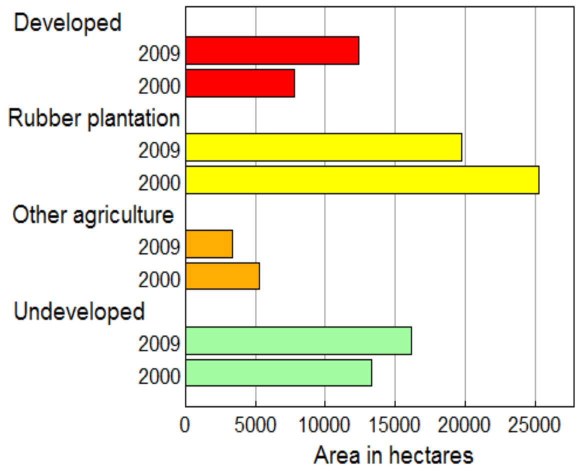

Fig.4: Bar chart of land-use in 2000 and 2009.

The map in Fig.5 illustrates land-use changes from 2000 to 2009. The left panel demonstrates land-use in 2000, whereas the right panel shows land-use in 2009, and the middle panel shows loss and gain of lands. Undeveloped and developed lands gained 4,557 ha and 2,872 ha, respectively. Agriculture and rubber plantation lost 1,970 ha and 5,459 ha to other categories, respectively.

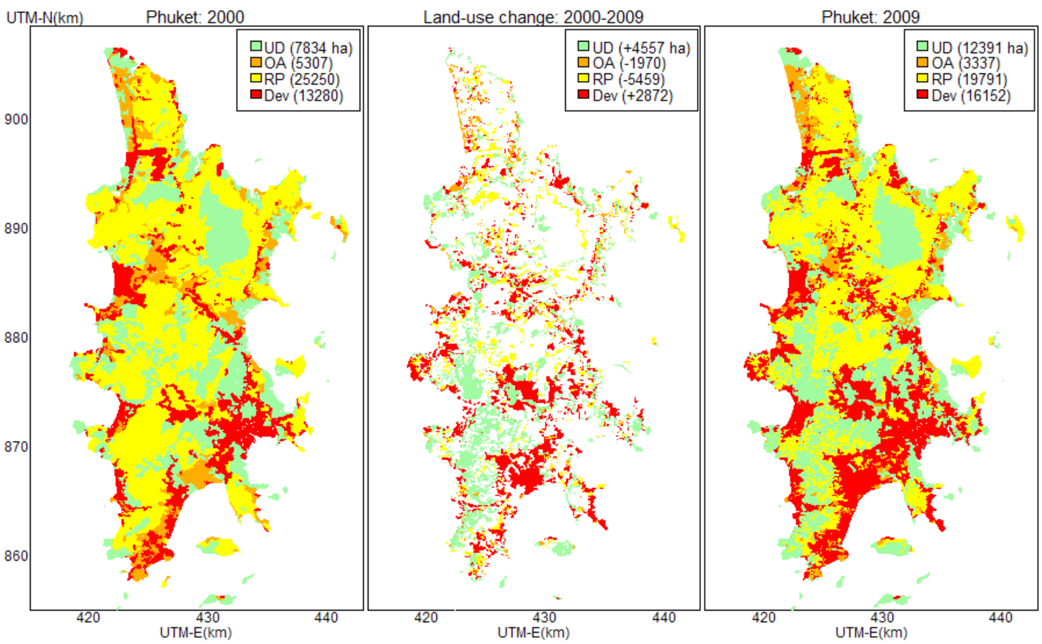

Fig.5: Land-use maps of Phuket province; 2000 (left), 2009 (right), panel highlighting areas where changes in land-use occurred (middle).

Modelling Result

Fig.6 shows crude percentages of developed lands for the two determinant factors (land-use in 2000 and sub-district identity) as red circles, together with a corresponding 95% confidence interval for differences between these percentages and the overall mean percentage (shown as the horizontal red line). The boxes show 95% confidence intervals which are coloured according to their location: above (cyan), across (yellow) or below (pink) the mean. For each factor, the confidence intervals are adjusted for the effect of the other factor, showing a result that adjusts for any correlation between determinants.

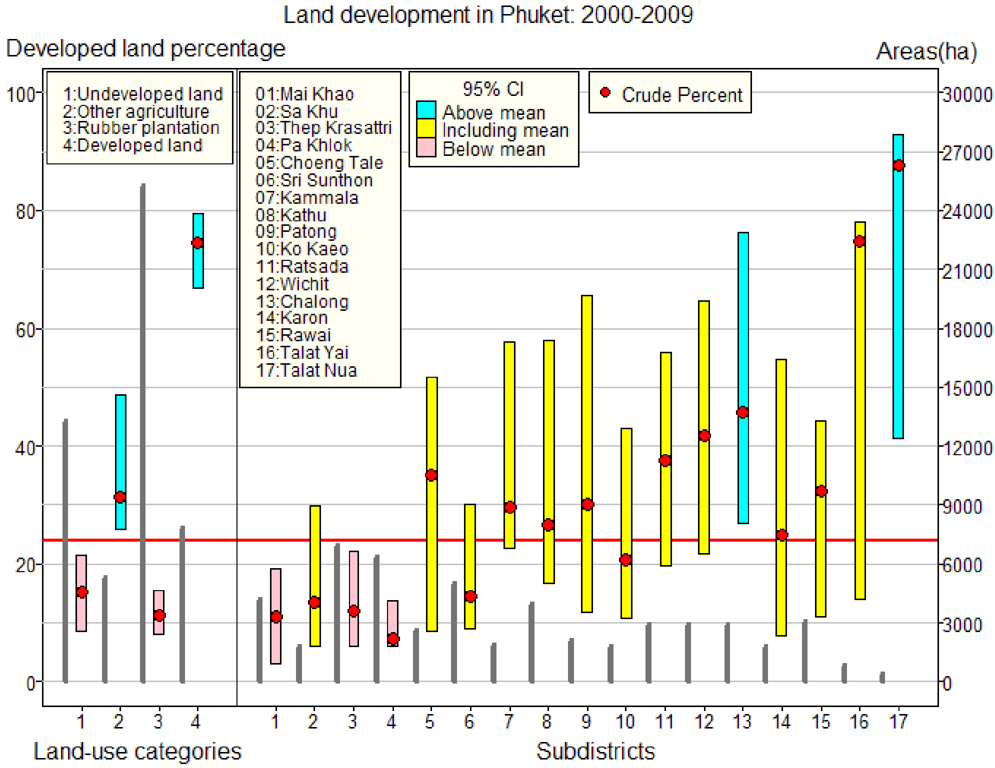

Fig.6: Adjusted percentages of land that changed to developed land in Phuket province (2000-2009), with coloured rectangles denoting 95% confidence intervals of percentage change by land-use categories and sub-district identity. Vertical bars denote sub-district in hectares.

The 95% confidence intervals for both other agriculture and developed lands in 2000 are higher than the mean whereas that for rubber plantation is lower. Thus, other agriculture and developed lands in 2000 were significantly more likely to change or remain as developed lands. The percentages of developed lands in Chalong and Talat Nua were all substantially above the mean. Thus, these two sub-districts were more likely to have significantly greater areas of developed lands than other sub-districts in 2009.

The full model with two factors was assessed using the ROC curve and compared with the simple model. Fig.7 shows the ROC curve for the simple model, with only land-use group in 2000 as the determinant factor, together with the ROC curve for the full model with both factors included.

The cut-off point in the curve, where the observed and the predicted numbers of developed land in 2009 are equal as the criteria, was used to report sensitivity and specificity of the model. The simple model gives AUC 0.751, with 60.6% sensitivity and 85.7% specificity, whereas the full model gives AUC 0.833 with 63.1% sensitivity and 88.3% specificity.

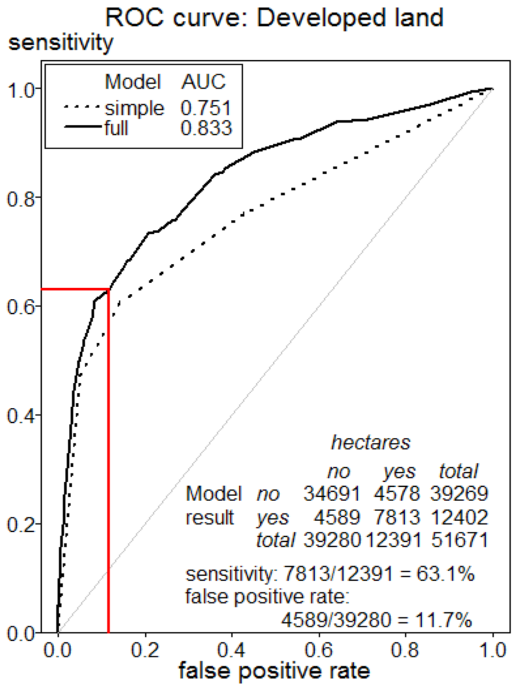

Fig.7: The ROC curve for logistic regression models with results from the full model.

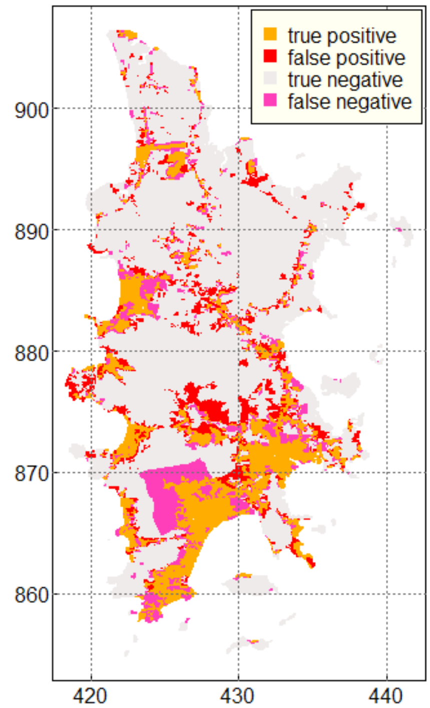

Fig.8: Results from the logistic regression model.

The map in Fig.8 illustrates the results from the logistic regression model. A false positive result indicates that the grid showed a developed land in 2009 when in fact it was not developed (the red area), while a false negative indicates that a land was not developed in 2009 (the result is negative), when in fact it was (the region shaded pink on the map). In both cases, the result is false. The pink and yellow areas show the incidence of developed land in 2009. The yellow areas on the map depict the areas which were correctly predicted as developed lands, while the pink areas also indicate the areas of developed lands that were incorrectly predicted by the model.

DISCUSSION AND CONCLUSION

In this study, logistic regression was used to model land development in Phuket from 2000 to 2009. It shows where land development would have probably occurred in 2009 compared to 2000. The results indicate that developed land was more likely to remain as developed land in 2009 and agricultural land was more likely to change to developed land in 2009. The findings of the current study show a similar pattern of land-use changes, especially from agricultural lands to developed lands, as those found elsewhere in the literature. A recent study on southern Thailand by Chuangchang and Tongkumchum (2014) found that the percentage of paddy fields and other agriculture (PF+) in the north location along highway 4 that had become developed lands was higher in 2000-2009 than in 1991-2000. In Banir Dar, Ethiopia, Haregeweyn *et al*. (2012) reported that built-up areas increased from 80 ha in 1957 to 155 ha in 1994, which were primarily converted from agricultural lands. For Delhi, during the period 1997-2008, Mohan *et al.* (2011) found that developed lands increased by17%, which were mainly due to conversion from agricultural and waste lands. For central Jordan, Alsaaideh *et al.* (2011) found that a high percentage of agricultural lands was converted to urban areas over the period of 1987-2005. A similar study by Forkuor and Cofie (2011) in Freetown, Sierra Leone, showed that 27% of agricultural lands in 1986 were converted for residential purposes in 2000. In the Al Gharbiya governorate of Egypt from 1972 to 2005, Belal and Moghanm (2011) reported that urban areas increased by 7.2 and 5.8%, causing losses of productive agricultural lands. Another study in Puerto Rico city by Lopez *et al.* (2001) showed that rapid losses of agricultural lands occurred as a result of urban expansion since 1950.

In our study of Phuket, land development mostly occurred in Chalong and Talat Nua sub-districts. These sub-districts are located in Mueang Phuket (the capital). Chalong is located in the central southern part of Phuket, where most visitors to the islands south of Phuket depart from Chalong pier. The number of tourists who visit the area is up to 3,000 per day, and the economy of the sub-district is growing. Moreover, Chalong is also located at the intersection of four roads (4021, 4022, 4024 and 4028). Road networks can influence the conversion of lands to developed ones. This can be clearly seen in a recent study in Lop Buri province of Thailand by Patarasuk and Binford (2012) which reported that developed lands occurred closer to road networks.

In order to confirm the model's capability, the ROC technique can be used in land-use change modelling studies (Pontius & Schneider, 2001; Hu & Lo, 2007; Wang & Mountrakis, 2011; Arsanjani *et al*., 2013). The ROC curves give the proportions of positive and negative outcomes that are correctly and incorrectly predicted by the model. AUC is currently considered as the standard method to assess the accuracy of such models. The AUC is a well-known method used in public health research. Although there are several scales for the AUC value interpretation, in general, the ROC curves with AUC below 0.75 are not considered as clinically useful (Worster *et al*., 2006). Moreover, the benefit of using logistic regression models to analyse land-use data is that the model can be extended when more than one predictor is needed to be investigated.

Understanding the pattern of land-use changes can be useful for planners and policy makers. It may improve their predictions of the amount of land-use change and the location of future developed land, as well as enhance existing urban strategies for better sustainable land management. Cities need the implementation of an effective urban plan, strict urban development regulations, as well as reduction of urban growth ratio to save fertile agriculture lands and protect the environment. Land-use planners can explore different land-use scenarios with different objectives and constraints.

Thailand's land-use database is updated every few years. It can provide a rich data resource for historians, property investors, environmental scientists and planning agencies concerned with the sustainable development of land.

The Thailand Department of Land Development has databases from regular surveys of thousands of plots in every province and data are not readily available later than 2009. This study focuses on methods, which are believed to be new and important, particularly because they can be integrated with remote sensing data on land covered from Earth-orbiting satellites. However, it is also important to have a method that makes appropriate use of historical land-use data such as those available from Thailand's Department of Land Development. For example, vegetation indices available from the MODIS polar-orbiting satellites could be incorporated into the proposed model, and further investigation of land-use change for tourism services based on the tourist population growth during the last decade would be desirable, using data available in the Phuket Master Plan.

Tourism is one of the major driving forces behind land-use changes. Phuket has been one of the most well-known tourist destinations for decades. Currently, the island has been transformed into a major tourism hub with well-prepared infrastructures and services to accommodate millions of tourists from around the world (Sakolnakorn *et al.*, 2013). Demand for tourism increases accommodation establishments, transport infrastructure and leisure activities all over Phuket. Differences in land development at the sub-district level are difficult to explain and this is a limitation in our study. Land-use changes relate not only to tourism activities but also to other factors including town planning and structure, road networks and population density (Belal & Moghanm, 2011; Patarasuk & Binford, 2012; Alsharif & Pradhan, 2014). This study, which is based on the available data, does not allow us to draw conclusions about land-use changes for tourism services in Phuket, and it is hoped that this issue can be addressed in further research.

ACKNOWLEDGEMENT

The authors acknowledge suggestions from Prof Don McNeil. We also would like to thank Thailand's Land Development Department for providing the land-use data. This study was supported by a scholarship granted by Prince of Songkla University.

REFERENCES

Allen, J. & Lu, K. (2003). Modeling and Prediction of Future Urban Growth in the Charleston Region of South Carolina: a GIS-based Integrated Approach. *Conservation Ecology*, *8*(2), 2.

Alsaaideh, B., Al-Hanbali, A., & Tateishi, R. (2012). Assessment of Land Use/Cover Change and Urban Expansion of the Central Part of Jordan Using Remote Sensing and GIS. *Asian Journal of Geoinformatics*, *11*(3).

Alsharif, A. A. & Pradhan, B. (2014). Urban sprawl analysis of Tripoli Metropolitan city (Libya) using remote sensing data and multivariate logistic regression model. *Journal of the Indian Society of Remote Sensing, 42*(1), 149-163.

Arsanjani, J. J., Helbich, M., Kainz, W., & Boloorani, A. D. (2013). Integration of logistic regression, Markov chain and cellular automata models to simulate urban expansion. *International Journal of Applied Earth Observation and Geoinformation*, *21*, 265–275.

Belal, A. A. & Moghanm, F. S. (2011). Detecting urban growth using remote sensing and GIS techniques in Al Gharbiya governorate, Egypt. *The Egyptian Journal of Remote Sensing and Space Science*, *14*(2), 73-79.

Boupun, P. & Wongsai, S. (2012). Land use change and the town planning policy of Phuket. *The 33rd Asian Conference on Remote Sensing*. Ambassador City Jomtien Hotel, Pattaya, Thailand.

Cheng, J. & Masser, I. (2003). Urban growth pattern modeling: a case study of Wuhan city, PR China. *Landscape and urban planning*, *62*(4), 199-217.

Chuangchang P. & Tongkumchum P. (2014). Modeling land development along highway 4 in Southern Thailand. *Songklanakarin Journal of Science and Technology, 36*(6), 719-725.

Chutinantakul, A., Mayeng, M., & Tongkumchum, P. (2014). Estimation of mortality with missing data using logistic regression. *Songklanakarin Journal of Science and Technology*, *36*(2), 249-254.

Eyoh, A., Olayinka, D. N., Nwilo, P., Okwuashi, O., Isong, M., & Udoudo, D. (2012). Modelling and predicting future urban expansion of Lagos, Nigeria from remote sensing data using logistic regression and GIS. *International Journal of Applied Science and Technology*, *2*(5), 116.

Fan, J., Upadhye, S., & Worster, A. (2006). Understanding receiver operating characteristic (ROC) curves. *Canadian Journal of Emergency Medicine*, *8*(1), 19-20.

Forkuor, G. & Cofie, O. (2011). Dynamics of land-use/land-cover change in Freetown Sierra Leone and its effects on urban and peri-urban agriculture- A remote sensing approach. *International Journal of Remote Sensing*, *32*(4), 1017-1037.

Hanley, J. A. & McNeil, B. J. (1982). The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*, *143*, 29-36.

Haregeweyn, N., Fikadu, G., Tsunekawa, A., Tsubo, M., & Meshesha, D. T. (2012). The dynamics of urban expansion and its impacts on land use/land cover change and small-scale farmers living near the urban fringe: A case study of Bahir Dar, Ethiopia. *Landscape and urban planning*, *106*(2), 149-157.

Helmer E. H. (2004). Forest Conservation and land development in Puerto Rico. *Landscape Ecology*, *19*, 29-40.

Herold, M., Menz, G., & Clarke, K. C. (2001). Remote sensing and urban growth models-demands and perspectives. In *Symposium on Remote Sensing of Urban Areas, 35*.

Hosmer Jr, D. W., & Lemeshow, S. (2004). *Applied logistic regression*. John Wiley & Sons.

Hu, Z. & Lo, C. P. (2007). Modeling urban growth in Atlanta using logistic regression. *Computers, Environment and Urban Systems*, *31*(6), 667-688.

Huang, B., Zhang, L., & Wu, B. (2009). Spatiotemporal analysis of rural-urban land conversion. *International Journal of Geographical Information Science*, *23*, 379-398.

Jiang, B. & Yao, X. (2010). Geospatial analysis and modeling of urban structure and dynamics: an overview. *In Geospatial Analysis and Modelling of Urban Structure and Dynamics* (pp. 3-11). Netherlands: Springer.

Kongchouy, N. & Sampantarak, U. (2010). Confidence intervals for adjusted proportions using logistic regression. *Modern Applied Science*, *4*(6), 1-7.

Lambin, E. F., Rounsevell, M. D. A., & Geist, H. J. (2000). Are agricultural land-use models able to predict changes in land-use intensity? *Agriculture, Ecosystems and Environment*, *82*(1), 321-331.

Lopez, T. del M., Aide, T. M., & Thomlinson, J. R. (2001). Urban expansion and the loss of prime agricultural lands in Puerto Rico. *Ambio: a Journal of the Human environment*, *30*(1), 49-54.

Muttitanon, W. & Tripathi, N. K. (2005). Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data. *International Journal of Remote Sensing*, *26*(11), 2311-2323.

Mohan, M., Pathan, S. K., Narendrareddy, K., Kandya, A., & Pandey, S. (2011). Dynamics of urbanization and its impact on land use/land cover: A case study of Megacity Delhi. *Journal of Environmental Protection*, *2*, 1274-1283.

Nong, Y. & Du, Q. (2011). Urban growth pattern modeling using logistic regression. *Geo-Spatial Information Science*, *14*(1), 62-67.

Patarasuk, R. & Binford, M. W. (2012). Longitudinal analysis of the road network development and land-cover change in Lop Buri province, Thailand, 1989-2006. *Applied Geography*, *32*(2), 228-239.

Pebesma, E., Bivand, R., Rowlingson, B., & Gomez-Rubio, V. (2014). R topics documented. Retrieved July 9, 2014, from http://rspatial.r-forge.r-project.org [July 9, 2014]

Pontius, R. G. & Schneider, L. C. (2001). Land-cover change model validation by an ROC method for the Ipswich watershed, Massachusetts, USA. *Agriculture, Ecosystems and Environment*, *85*, 239-248.

Prabnarong, P. & Thongkao, S. (2006). Land Use Changes in Pak Panang Bay using Arial Photographs and Geographic Information System. *Walailak Journal of Science and Technology (WJST)*, *3*(1), 93-104.

Rao, J. N. L. & Scott, A. J. (1992). A sample method for the analysis of clustered binary data. *Biometrics*, *48*(2), 577-585.

Ratanasermpong, S., PornprasertchaI, J., & Disbunchong, D. (1995). *Natural resources and land use changes of Phuket using remote sensing*. The 16 Asian Conference on Remote Sensing. Phuket, Thailand.

Sakar, S. & Midi, H. (2010). Importance of assessing the model adequacy of binary logistic regression. *Journal of Applied Sciences*, *10*(6), 479-486.

Sakolnakorn, T. P. N., Naipinit, A., & Kroeksakul, P. (2013). Sustainable Tourism Development and Management in the Phuket Province, Thailand. *Asian Social Science*, *9*(7), 75-84.

Swangjang, K. & Iamaram, V. (2011). Change of Land Use Patterns in the Areas Close to the Airport Development Area and Some Implicating Factors. *Sustainability*, *3*, 1517-1530.

Schneider, L. C. & Pontius, R. G. (2001). Modeling land-use change in the Ipswich watershed, Massachusetts, USA. *Agriculture, Ecosystems and Environment*, *85*(1), 83-94.

Takahashi, K., Uchiyama, H., Yanagisawa, S., & Kamae, I. (2006). The logistic regression and ROC analysis of group-based screening for predicting Diabetes incidence in four years. *Kobe Journal of Medical Sciences*, *52*(6), 171-180.

Tayyebi, A., Perry, P. C., & Tayyebi, A. H. (2014). Predicting the expansion of an urban boundary using spatial logistic regression and hybrid raster-vector routines with remote sensing and GIS. *International Journal of Geographical Information Science*, *28*(4), 639-659.

Thinnukool, O., Chuangchang, P., & Kongkraphan, K. (2014). Analyzing land-use change using grid-digitized method. *Songklanakarin Journal of Science and Technology*, *36*(2), 235-240.

Thomlinson, J. R. & Rivera, L. Y. (2000). Suburban growth in Luquillo, Puerto Rico: some consequences of development on natural and semi-natural systems. *Landscape and Urban Planning*, *49*(1), 15-23.

Tongkumchum, P. & McNeil, D. (2009). Confidence intervals using contrasts for regression model. *Songklanakarin Journal of Science and Technology*, *31*(2), 151-156.

Wang, J. & Mountrakis, G. (2011). Developing a multi-network urbanization model: a case study of urban growth in Denver, Colorado. *International Journal of Geographical Information Science*, *25*(2), 229-253.

Worster, A., Fan, J., & Upadhye, S. (2006). Understanding receiver operating characteristic (ROC) curves. *Canadian Journal of Emergency Medicine, 8*(1), 19-20.