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Modelling Land Use Change using Cellular Automata Model: A Case Study of Wangthong City, Phitsanulok province, Thailand.

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Abstract

This research aims to study the analysis of land use change in order to create spatial land use change model using cellular automata model and to predict land use change in the future in Wangthong City, Phitsanulok province, Thailand. The model is calibrated with 2005 and 2015 data using satellite image from LANDSAT and land use classification using object-based classification method. The model is used to predict land use change in 2025. In this research, land use was classified into 4 classes including Urban and build-up area, Agricultural land, Forest land and water body. Two datasets of distance from the road and slope variables were used to predict land use change using cellular automata model. Land use map of 2005 is used to predict the future land use using cellular automata model. The findings reveal that urban growth pattern is peri-urban development since 2005 to 2015. Urban and build-up area is the area that increases the most. In 2015, Urban increase 18.44 square kilometer from 2005. Forest land is decreased 67.46 square kilometer to 677.91 square kilometer in 2015 from 745.37 square kilometer in 2005. Most land use change in this research is affected by population's growth in Phitsanulok city.

Keywords: Cellular Automata;CA, Land Use Change, Land Use Classification, Model Validation

1. Introduction

In present, land use and land cover in Thailand have been changing constantly. Each area has different land use change patterns depending on several concerned factors. One of key factors which drive the land use change is increment of population. In year 1999, there are 61 million people in Thailand. ; there are around 6.6 million population lived in urban areas. In years 2014, population increased to be 65 million which is about 7% of the population in year 1999; which around 22 million people lived in cities (more than 300% increased from year 1999). The trend is still increasing every year. From the above reason, land use change is driven due to more need of natural resources including the need of land for residence, the need to use natural resources for living (e.g. water, food etc.). The study of land use change and modeling predicted land use change are definitely vital for effective future plans. To do this, we need to apply better strategic plans that affect minimal impacts to the environment, and manage limited natural resources efficiently (Yaolong and Murayama, 2010).

Wangthong city is one of cities that land use rapidly and continuously changes. In the past, this area was mostly covered by forest. Urban and build-up areas were small and population was less. During these years, most areas were turned to agricultural area and the small community became bigger. Currently, urban area in Wangthong city has been expanding and the population has been increasing. One of reasons is due to Wangthong City is located closed to center of Phitsanulok major city. It was therefore influenced by urban expansion and population movement (Piyathamrongchai, 2013). The complexity of the land use change is probability of the land use change from one to many land use are differently. For example, agricultural area is influenced from urban growth; there is a high probability that agriculture will change to urban area and also agricultural land will be increased by changing forest land. For these reasons, this study represents a simulation model applying cellular automata model to construct a spatial land use change model which is developed based on real land use data extracted from multi-date satellite images. The model was finally used to simulate land use change in the future (Xin Yang et al., 2014).

2. Objectives

1. To analyze land use change from the past to the present in Wangthong city.
2. To develop spatial land use change model using cellular automata model.
3. To predict land use change of Wangthong city in the future

3. Study area

Wangthong city is located in east part of Phitsanulok province, between 16°32'43.2"N to 17°09'18.6"N and 100°18'05.0"E to 100°56'38.7"E. (see Fig.1) Entire area covers 1,687 km^2 and covers 11 sub-districts. This area is majorly covered by forest. Population in Wangthong district is proximately 121,254 and there are 41,760 households; population density is 71.8 people per square kilometer (Department of provincial administration, 2015). The most population live in Ban Krang sub district which has around 20,000 people (16.7% of population in Wangthong district).

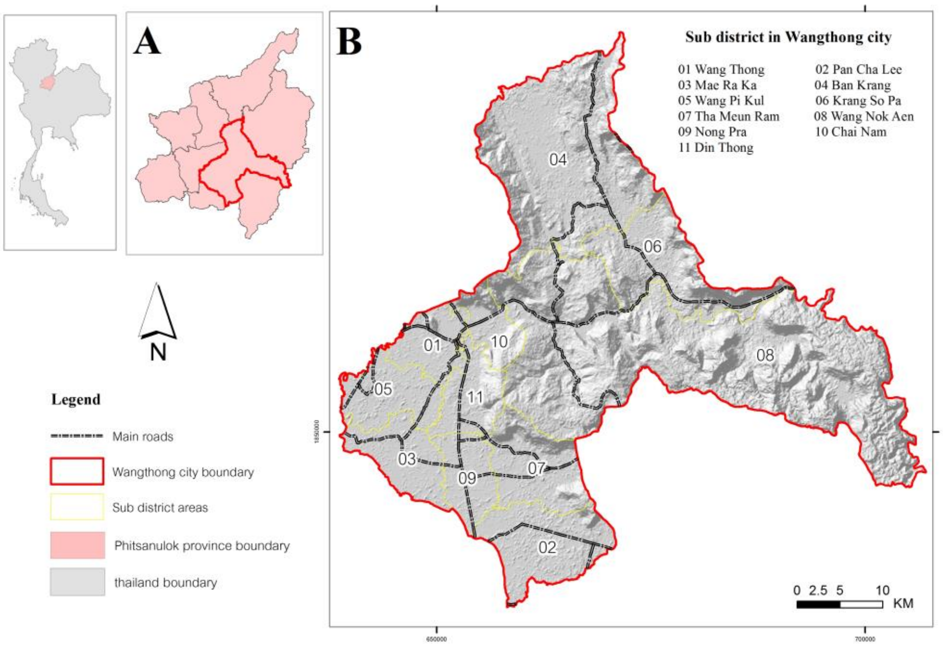

Fig. 1. Study area: (A) Wangthong city boundary in Phitsanulok province; (B) Sub district in Wangthong city.

4. Data and Methodology

The spatial land use change model was developed using cellular automata model. The model was constructed based on actual land use data synthesized from multi-date satellite images in year 2005 and 2015, which were used for validation and calibration. Whereas the simulation was applied to predict land use change though the year 2025. The data used and processes implemented are shown in Fig. 2.

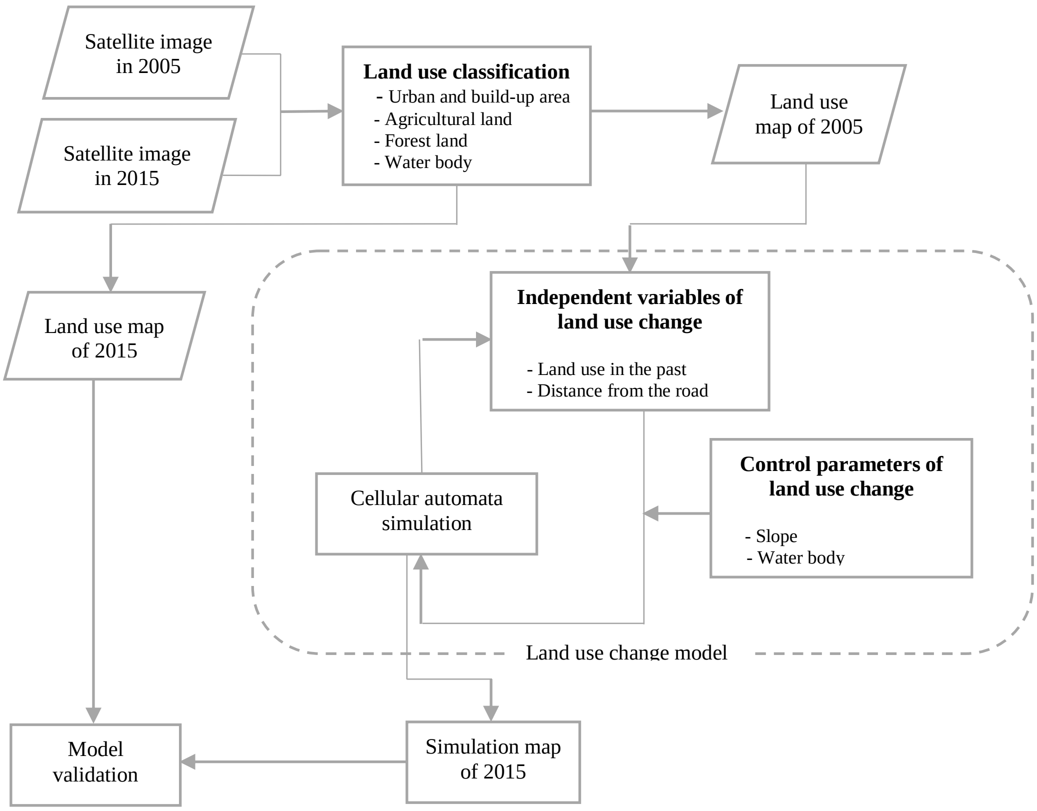

Fig.2. Conceptual framework and methodology.

This research focuses on the study of land use change in Wangthong city using cellular automata model. The model was created and used to simulate the land use change based on actual dataset. Methodology of this study is depicted as follows:

4.1 Image classification

Image classification was applied based on LANDSAT images with in years 2005 and 2015. The object-based classification method was used in order to categorize land use/cover. In this research, land use was classified into 4 classes including urban and build-up area, agricultural land, forest land and water body.

4.2 The integrated land use change model

This study applied cellular automata model to develop spatial land use change model. The python script language was used as the main tool to construct the land use change model.

Cellular automata model is mathematical model that composes of space or cellular space. Each cell has state, which generally is a real number (Oxman et al., 2013). The state of cell is modified in each time step depend on transition rules or transition functions which are applied to 8 neighborhood cells (Moore neighborhood).

The transition rules in this study are defined as follows (see Fig3):

1) Water body is stable; nothing will change if the target cell is water body.

2) Any cell which has more than four urban and build-up area neighborhood cells—the target cell will turn to urban and build-up area in the next time step.

3) Any cell which has more than five agricultural land neighborhood agricultural land cells—the target cell will change to agriculture cell in the next time step.

4) The forest area is stable, if slope is more than 35%.

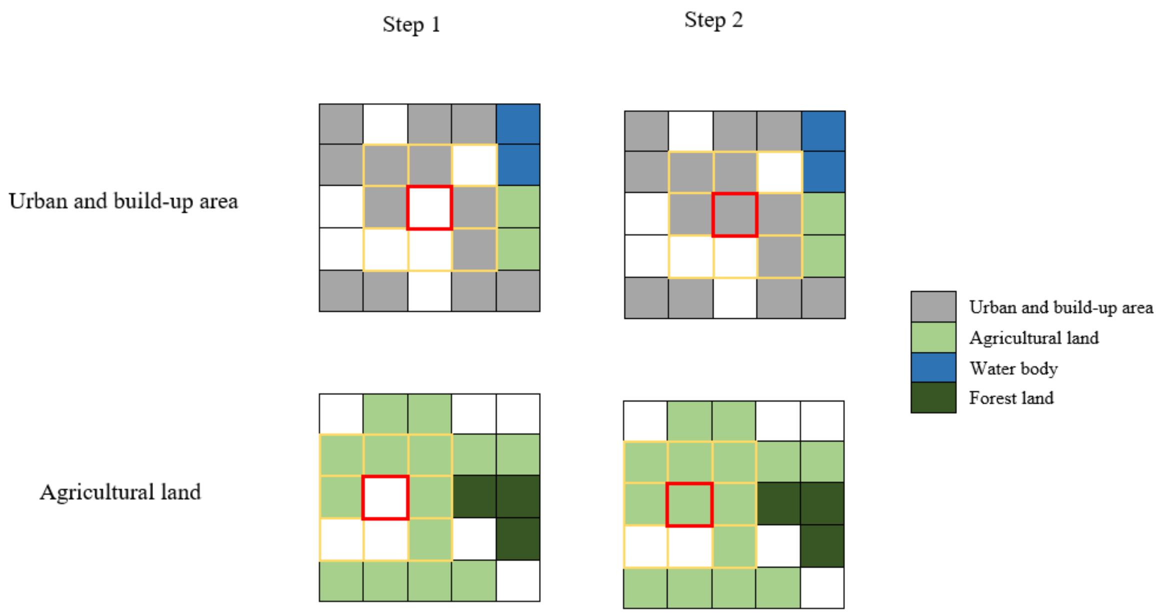

Fig. 3. Example of cells that change from one state to another using defined transition rules.

4.3 Model validation

In this study, the model was validated by comparing two different date land use maps classified from satellite data in year 2015 and image generated from the simulation model. The accuracy matrix was applied to analyze the accuracy of the results. (Puertas et al., 2013)

5. Results and discussion

From image classification, land use was classified into 4 classes including urban and build-up area, agricultural land, forest land and water body between 2005 and 2015. The result show that agricultural land is mostly increased as described follows:

Table 1. Areas of land use from land use classification

Classes	2005(km^2)	2015 (km^2)
Urban and build-up area	73.4	91.9
Agricultural land	883.3	931.2
Forest land	745.4	677.9
Water body	12.3	13.4
Total	1714.3	1714.3

The results simulated from cellular automata model are shown in Fig.4. Two datasets including distance from road network and slope were used as constraints to make the model more reliable. It is clearly show that the CA model developed in this study yield high accuracy compare to actual land use data. According to the accuracy matrix, the overall accuracy is about 89%, which is fairly acceptable level. Table 2 represents measured area of simulated map compare to actual data that classified from satellite image. The most different class is build-up area. On the other hand, which the simulated result is similar to the actual data, is agricultural land.

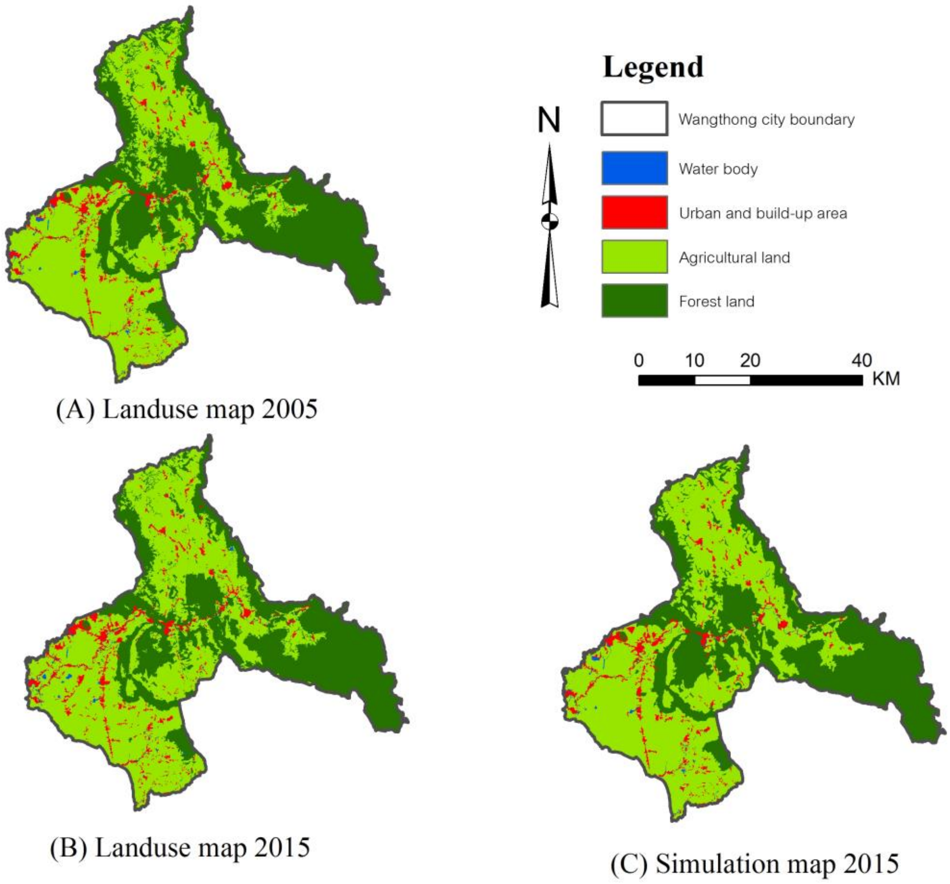

Fig. 4. (A) Land use map of 2005, (B) Land use map of 2005, (C) Simulation map of 2015

Table 2. Area difference between actual data and simulated result in year 2015

Classes	Actual data 2015 (*km*^{2})	Simulation 2015 (*km*^{2})	Difference between actual data and simulation
Urban and build-up area	91.9	76.3	-15.6
Agricultural land	931.2	934.1	+2.9
Forest land	677.9	691.6	+13.7
Water body	13.4	12.3*	-1.1
Total	1714.3	1714.3	-

*water body remains unchanged according to land use in 2005

The results from this research can be recommended as a prototype model for government or other concerned organizations who need to plan for land use change in the future. This will beuseful for infrastructure development plan,which willsupport urban expansion and urban population growth effectively. Morever, private organizations can also bring this approach to take advantage in variety fields. For instance, they can use the results as base for assessing the land and property value and/or use for identifying suitable locations for service and commercial building such as hospital and department store, etc. in the future.

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