International Journal of GEOMATE, July, 2018 Vol.15, Issue 47, pp.201-208
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.47.SGI174
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

LAND USE/COVER CHANGE AND LANDSCAPE FRAGMENTATION ANALYSES IN KHON KAEN CITY, NORTHEASTERN THAILAND

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ABSTRACT: The aim of this study is to determine the land use and land cover changes in Khon Kaen city, Thailand, using landscape fragmentation analysis together with multi-temporal Landsat data acquired during 1990-2015. Using support vector machine techniques, multi-temporal Landsat imagery was classified to derive a map of land use and land cover change and subsequently analyze the landscape fragmentation to determine the factors driving this change. The results showed that most of the built-up area was converted from an agricultural area, illustrating the expansion of the urban area over the past twenty-five years. Consequently, the landscape has become more highly fragmented as indicated by an increase in the patch number and a decrease in the mean patch size of the agriculture land cover class. Economic development, education system development, population growth and the improvement of traffic infrastructure are main factors driving land use and land cover change in Khon Kaen city.

Keywords: Landsat imagery, Landscape fragmentation, Driving factors, Khon Kaen

1. INTRODUCTION

During the past two decades, most of the countries in the Greater Mekong Sub-region (GMS) of Southeast Asia have become emerging economies. In addition, the major cities of this region are in a new era of economic cooperation due to the impact of the ASEAN Economic Community (AEC) [1]. Within the major cities of the GMS countries, Khon Kaen city (KKC) has played a crucial role as an important hub for logistics and health care. Since KKC is the gateway to the northeastern part of Thailand, it is also a small regional center for administration, education, financial, governmental services and agriculture [2]. Accordingly, the population and the spatial extent of the urban area in the KKC have rapidly increased, and the natural resources, such as woodlands and agricultural areas, are being replaced, causing land use fragmentation [2]-[3]. Inevitably, the land use/land cover (LULC) of KKC has rapidly changed. Therefore, it is very interesting to evaluate the development of KKC by analyzing the factors driving the LULC changes using landscape fragmentation analysis.

The aim of this study is to determine the LULC changes between and landscape fragmentation for the years 1990 and 2015 in KKC of Thailand using the LULC data derived from Landsat imagery. A support vector machine (SVM) technique was used to classify the multi-temporal Landsat data into LULC maps, while FRAGSATS® was used to analyze the landscape fragmentation in KKC. Subsequently, the factors driving the LULC change were derived.

2. REVIEW OF LITERATURES

The industrialization era has transformed rural areas into urban areas in a process usually called urbanization. These changes have many negative effects on the environment such as the pollution of water, air, and land and causing climate change. Land cover can be observed using remote sensing techniques and data collection in the field. However, land use and land use change generally have to be characterized by integrating natural science and social science methods to determine which human activities are taking place in different regions of the landscape [3].

Many past studies [3]-[6] have fruitfully shown the potential of multi-temporal Landsat imagery for the determination of LULC changes. Landsat multispectral scanner (MSS), Landsat thematic mapper (TM) and Landsat enhanced thematic mapper plus (ETM+) images from 1976, 1988, and 2000, respectively, together with socio-economic data, were employed to evaluate the spatial dynamics of LULC change and to characterize urban expansion in Nairobi, Kenya [3]. Landsat MSS and Landsat ETM+ datasets for 1973 and 2000, respectively, were utilized to study LULC

and landscape fragmentation in the Bindura district, Zimbabwe, in order to determine the driving factors for LULC change [4]. In Asia, Landsat TM datasets from 1988 and 1995 were classified to analyze land use change in Changping district, Beijing, China [5]. In addition, an assessment of LULC from 1965 to 2015 in Tam Giang-Cau Hai Lagoon, Thua Thien Hue Province, central Vietnam, was conducted using a Landsat dataset together with remotely sensed data acquired from other satellites, such as ASTER and SPOT5 [6]. Hence, it is possible to use multi-temporal Landsat series to determine the LULC changes in order to obtain the factors driving LULC change and to model future LULC. Thus, in this study, a dataset of multi-temporal Landsat imagery acquired during the 1990-2015 period together with ENVI image analysis software were utilized to derive the LULC changes in KKC, Thailand.

When using the LULC information from remote sensing data, it is important to conduct landscape fragmentation analysis to derive a number of variables that measure fragmentation [7]. LULC changes can be determined by measuring the landscape connectivity [8]. To calculate a wide variety of landscape metrics for categorical map patterns, FRAGSATS® software was therefore employed.

3. STUDY AREA

KKC is the capital of Khon Kaen province and is located 445 km to the northeast of Bangkok, the capital city of Thailand (16°25' - 16°38'N, 102°41' - 102°50'E), as shown in Fig. 1. In this study, KKC covers an area of approximately 520 km^2, encompassing ten sub-districts comprising the Nai Muang, Sila, Bueng Niam, Phra Lap, Mueang Kao, Tha Phra, Ban Pet, Sam Ran, Daeng Yai and Ban Kho sub-districts.

In the study area, each sub-district has a different major economic activity. The Nai Mueang district is not only the administration center but also the center for education, financial institutions, and many shopping centers. Therefore, it is the most densely populated area in this study area [9]. The five areas to the north and south of the Nai Mueang area, namely, the Sam Ran, Sila, Tha Phra, Ban Pet and Mueang Kao districts, are being rapidly developed. In these areas, many shopping centers, service centers, residential areas and industrial zones have been established over the past few decades. However, the northwest and southeast districts, namely, the Bueng Niam, Phra Lap, Deang Yai and Ban Kho districts, are still mainly utilized for agricultural activity.

4. DATA AND METHODS

4.1 Satellite Imagery and Ancillary Data

Landsat TM data from 1990, Landsat ETM+ data from 1999 and Landsat operational land imager (OLI) data from 2015 were used to evaluate the LULC in the study area (Table 1). Land use data for 1992 and 2002 provided by the Land Development Department (LDD) were used as a reference for the accuracy assessment process.

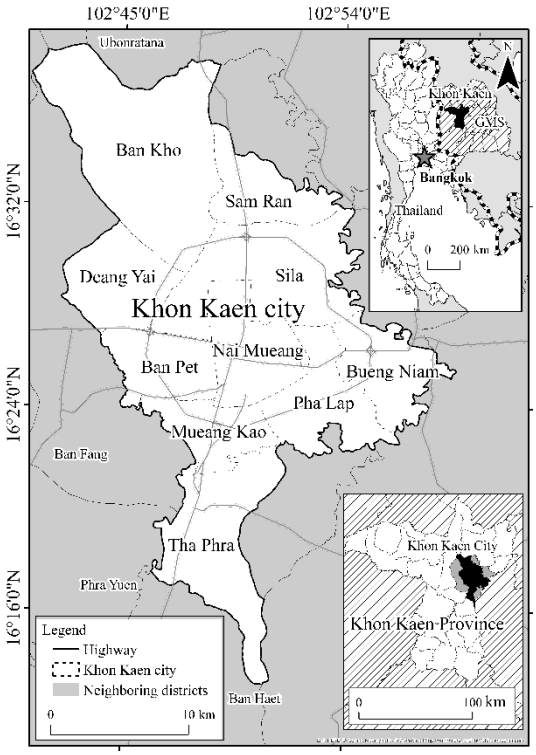

Fig. 1 Khon Kaen city (KKC) in this study including ten sub-districts, namely, the Nai Muang, Sila, Bueng Niam, Phra Lap, Mueang Kao, Tha Phra, Ban Pet, Sam Ran, Daeng Yai and Ban Kho sub-districts.

Table 1 Multi-temporal Landsat imagery used to classify LULC

Satellite	Path/Row	Acquisition Date
Landsat TM	128/49	Dec 26, 1990
Landsat ETM+	128/49	Nov 27, 1999
Landsat OLI	128/49	Dec 31, 2015

4.2 Classification of LULC in KKC

In this study, an SVM classifier was used to perform a supervised classification of Landsat dataset for each year into five classes (Table 2), namely, (1) agriculture (AG), (2) built-up area (BA), (3) green area (GA), (4) water body (WB),

and (5) bare land (BL). The SVM technique is robust, accurate and effective even when using a small training sample. Many studies have shown that SVMs are not sensitive to training sample size, and these approaches have been improved to successfully work with a limited quantity and quality of training samples [10]. In addition, since the number of training samples for the 1990 and 1999 datasets is relatively small and limited, the SVM technique is, therefore, suitable for use in this study. Then, the LULC maps derived from the Landsat imagery were checked for accuracy by a comparison with reference data. Specifically, for the 1990 and 1999 LULC maps, these data were compared to the reference 1992 and 2002 land use maps provided by LDD, respectively. For the 2015 LULC map, Google Maps was used as the primary reference and global positioning system (GPS) points taken during fieldwork from December 2015 to February 2016 were employed as secondary reference data.

Table 2 Land use/cover classes

LULC	Description
Built-up area (BA)	Area containing man-made structures
Agriculture (AG)	Area in which crops are cultivated for commercial proposes
Water body (WA)	River and reservoirs
Green area (GA)	All wooded areas and scrubland
Bare land (BL)	All open areas

According to 1990, 1999 and 2015 LULC maps, a change detection module in ENVI® software was used to determine the changes in land use/cover between 1990 and 2015. Then, FRAGSATS® was used to analyze the landscape fragmentation at the class level with four landscape metrics, and finally, the factors driving these changes were investigated.

4.3 Landscape Fragmentation

At the class level, FRAGSATS® was used in order to calculate landscape metrics for categorical map patterns. In this study, following four landscape metrics including (1) the number of patches (NP); (2) the mean patch size (MPS); (3) the largest patch index (LPI); and (4) the interspersion and juxtaposition index (IJI) were selected. These landscape metrics were chosen because they can illustrate changes in land use activity, as demonstrated by past studies [4].

5. RESULTS AND DISCUSSION

5.1 Accuracy Assessment

A comparison with the reference data shows that the overall accuracy levels range from 94% to 98% and the kappa index is 0.9 (Table 3). The results satisfy the minimum 85% accuracy stipulated by the Anderson classification scheme [11], indicating the reliability of the LULC maps (Fig. 2).

Table 3 Accuracy assessment of the LULC maps

Class	1990		1999		2015	
	PA %	UA %	PA %	UA %	PA %	UA %
BA	93	99	89	85	94	96
AG	98	99	94	98	96	95
WB	96	97	99	87	95	98
GA	96	88	93	88	89	95
BL	97	83	98	82	83	73
OA (%)	98		94		94	
KI	0.9		0.9		0.9	

Note: OA: overall accuracy; KI: kappa index;
PA: producer's accuracy; UA: user's accuracy

5.2 The 1990, 1999 and 2015 LULC Maps

As presented in Table 4 and Fig. 2, the main activity of KKC was agriculture. In the study area, in 1990, the top three LULC classes were AG, BA, and GA, which occupied 91%, 3%, and 3% of the total area, respectively, while WA and BL occupied less than 3%. Additionally, in 1999 and 2015, the top three LULC classes were the same as those in 1990. In 1999, AG, BA, and GA occupied 88%, 4%, and 5% of the total area, respectively, while the others exhibited no change. However, in 2015, the proportion of AG rapidly decreased by approximately 13%, while that of BA, GA, and WA significantly increased by approximately 7%, 5%, and 2%, respectively. The results of the change detection analyses, as shown in Fig. 3 and Table 5, demonstrated that the changes in LULC "from AG to BA" as well as "from AG to GA" were the major LULC changes. The change in LULC class "from AG to BA" is indicative of the high rate of urbanization occurring over these 25 years (Table 5).

5.3 Fragmentation Analyses at the Class Level

According to the fragmentation analyses (Figs. 4 to 7), the ten sub-districts KKC can be divided into the following 4 groups as shown in the inset map of Fig. 3: the (1) urban, (2) lowland, (3) highland, and (4) mixed rangeland groups. Each group contains sub-districts having similar

landscape metric indicators, which will be described as follows.

Table 4 LULC of study area from 1990 to 2015

Class	1990		1999		2015	
	km^2	%	km^2	%	km^2	%
BA	18	3	23	4	59	11
AG	506	91	489	88	414	75
WB	11	2	11	2	18	3
GA	15	3	28	5	58	10
BL	3	1	2	1	4	1
Total	553	100	553	100	553	100

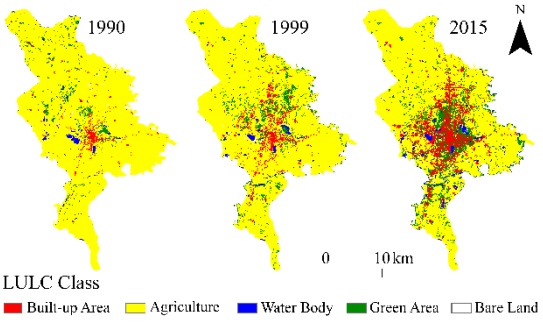

Fig. 2 LULC maps of KKC in 1990, 1999, and 2015

Group 1 (G1): an urban group comprising the Nai Mueang, Sila, Mueang Kao, and Tha Phra sub-districts had a similar trend in LULC change from AG to BA, as shown in Fig. 3. From Fig. 4 to 7, in this group, the NP, MPS, LPI, and IJI of BA increased, indicating the continuous expansion of settlement areas. However, only the NP of AG increased, while the other landscaped metrics for this class decreased, illustrating the changes in LULC from AG to BA, corresponding to the results of the change detection analysis.

Group 2 (G2): the lowland group consisting of Bueng Niam and Pha Lap sub-districts is mainly dominated by AG, as shown in Fig. 4. In this group, the NP of AG increased, while the MPS, LPI and IJI decreased (see Fig. 5 to 7), indicating a change in LULC from AG to the other LULC classes, particularly the WA class. This result is because this group is located in the lowland area and is consequently often submerged by flooding during the wet season. Additionally, the major activity of the local communities in this group is the cultivation of rice paddies. Therefore, the people in this area have attempted to increase the number of small reservoirs in order to store any excess flood water for subsequent use in planting off-seasonal rice paddies during the dry season. This reasoning can be confirmed by the increases in the NP, MPS, LPI and IJI of WA (see Fig. 4 to 7) as well as the results of the change detection analysis shown in Fig. 3 and Table 5.

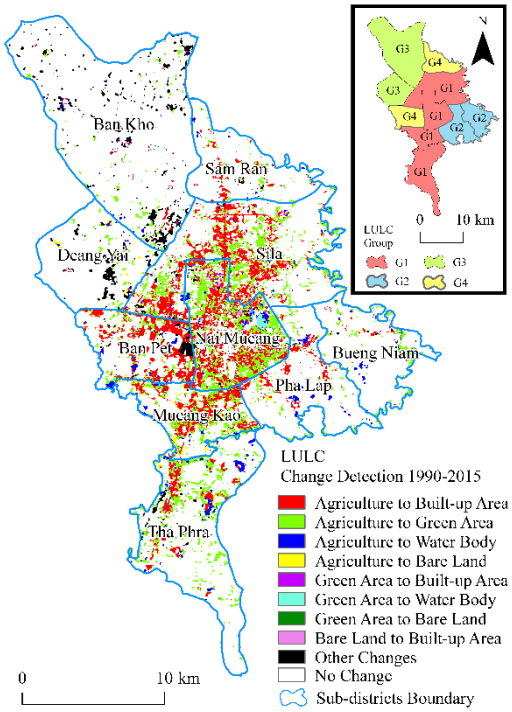

Fig. 3 LULC changes map of KKC during 1999 – 2015

Table 5 Major LULC change rates

From class	To class	1990 - 2015	
		Area (km^2)	km^2/year
No change		395	-
Agriculture	Built-up area	46	2
	Green area	51	2
	Water body	9	Less than 1
	Bare land	3	Less than 1
Green area	Built-up area	1	Less than 1
	Water body	1	Less than 1
Other changes		11	Less than 1

Group 3 (G3): the high land with the Ban Kho and Daeng Yai sub-districts was also mainly dominated by AG. As shown in Fig. 3, most of the LULC in this group experienced no change. In these areas, the NP of AG decreases, while the MPS increased, illustrating that people are still working engaged in agricultural activities. In addition, the LPI and IJI of AG (see Fig. 6 and 7) in this area change slightly, indicating that this LULC class experienced no change. This finding was confirmed by the field observations, which found that

rice paddy and sugar-cane cultivation are the major activities of this group.

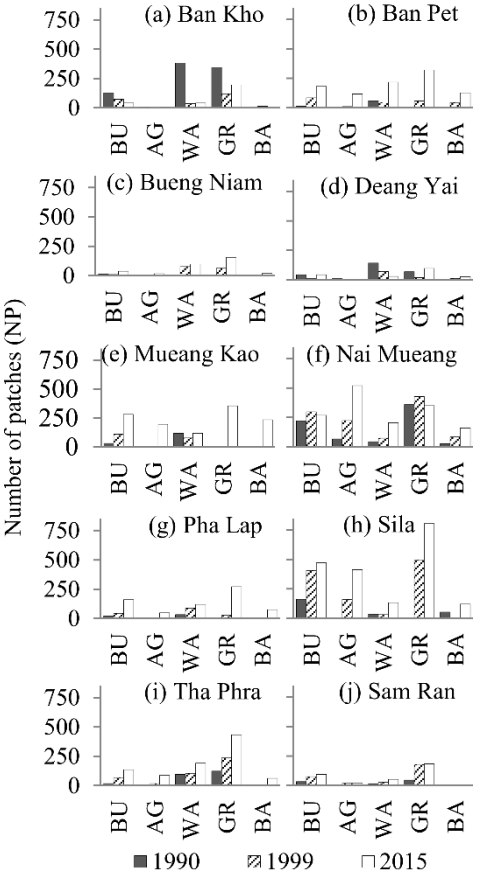

Fig. 4 Number of patches (NP) for each LULC class in the ten sub-districts in 1990, 1999 and 2015

Group 4 (G4): the mixed rangeland group consists of the Ban Pet and Sam Ran sub-districts. The major LULC types of this group were AG and BA, as shown in Fig. 2. The NP and IJI of AG and BA increased. In addition, the MPS and LPI of AG decreased (see Fig. 5 and 6), while these two landscape metrics for BA increased, indicating a tendency to change LULC from AG to BA. This finding illustrated that in the future, these two sub-districts will be urbanized since both the MPS and LPI indicators show the increasing connectivity of BA. Through field observation, it was found that many paddy fields were converted into accommodations, corresponding to change detection analysis results shown in Fig. 3.

5.4 Factors Driving Landscape Fragmentation

According to the analysis of the landscape metrics, the LULC in the G1 and G4 areas is urbanized, while the LULC in the other two groups (G2 and G3) is still used for agricultural activity. In addition, the LULC in G1 area changed rapidly, influenced by the interactions of population and socio-economic and physical forces described in the following.

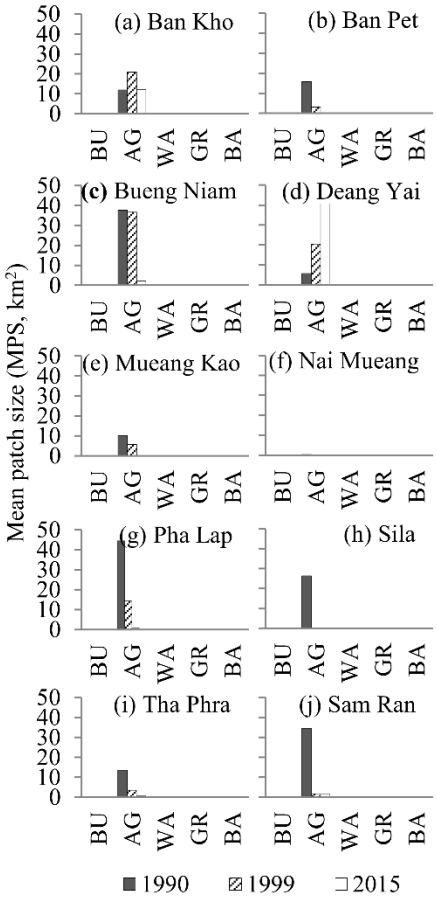

Fig. 5 Mean patch size (MPS) of each LULC class in the ten sub-districts in 1990, 1999 and 2015

5.4.1 Population growth

Census data distributed by the Department of Provincial Administration of Thailand indicated that the population increased from 207,996 in 1990 to 303,540 in 2015 [9]. The population has increased every year, and the demand for housing has increased likewise to meet the needs of residents. Subsequently, infrastructure has to be developed in order to serve the citizen demands. This growth has been shown through census data on the number of new registered houses in the study area. The number of houses was 149,483 in 2015, which increased three-fold compared to that in 1993 (50,463 houses) [9]. These data indicated that population expansion is a driving force of LULC change and landscape fragmentation.

5.4.2 Economic development

According to the census data [9], it was found that during 1990 - 2015, the gross provincial product (GPP) of Khon Kaen province increased. The GPP was approximately 28,000 million baht in 1995, 65,000 million baht in 1999, and 193,000

million baht in 2015 [12]. These data show that Khon Kaen province has rapid economic growth that influenced to the change in LULC in KKC, which is evidenced by the appearance an increasing number of shopping malls, service centers and industrial factories such as those producing fishing nets, goods for women, and paper. The increase in economic development as measured by the rise in GPP values reflects the change in urban area expansion, which is further evidenced by the changes in LULC from AG to BA in the areas around department stores and service centers during the past 25 years (Fig. 8).

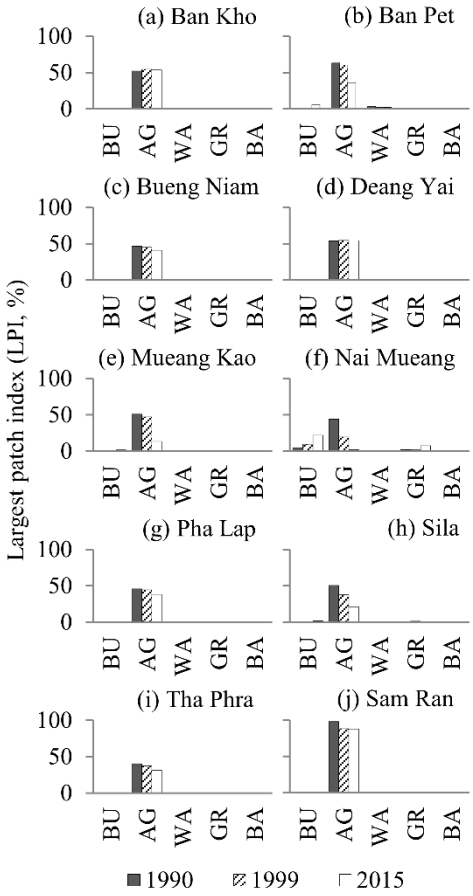

Fig. 6 Largest patch index (LPI) of each LULC class in the ten sub-districts in 1990, 1999 and 2015

5.4.3 Education development

KKC is a regional center for academia in the northeastern part of Thailand. At present, there are eleven educational institutes, including three higher educational institutes, namely, Khon Kaen University (KKU), Rajamangala University of Technology Isan (RMUTI: Khon Kaen campus), and Northeastern University (NEU). These three universities have the facilities and personnel to accommodate the increasing number of Thai as well as foreign students. During the past two decades, the increasing number of students has led local business to develop places of accommodation in order to serve the demands of these students. From the results of LULC classification, it can be seen that the areas around these three universities experienced significant changes over the past 25 years, corresponding to the increase in BA along with the decrease in AG, as shown in (Fig. 8).

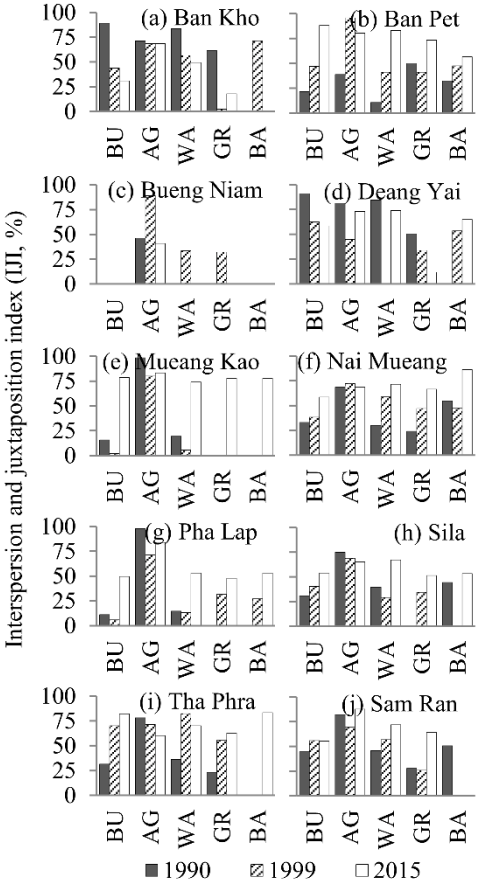

Fig. 7 Interspersion and juxtaposition index (IJI) of each LULC class in the ten sub-districts in 1990, 1999 and 2015

5.4.4 Traffic infrastructure

The transportation network, such as the Mittraphap superhighway and railroad track used to connect Bangkok and Vientiane, as noted by [2], bisect KKC into eastern and western sides, as shown in Fig. 8. From 1990 to 1999, BA grew mostly on the eastern side of KCC, especially the area surrounding the railway station. In addition, from 1999 to 2015, the areas on both sides of KCC were rapidly converted into BA. Based on an in-depth interview of ten local people who have lived in KKC for more than 25 years, the findings indicated that during the first ten years (1990 – 1999) of our study period, the Mittraphap superhighway was changing from a two-lane road to a four-lane road. In addition, during the next 15 years (1999 – 2015), the layout of the Mittraphap

superhighway was changing to its ultimate design, resulting in the growth into an eight-lane or ten-lane road.

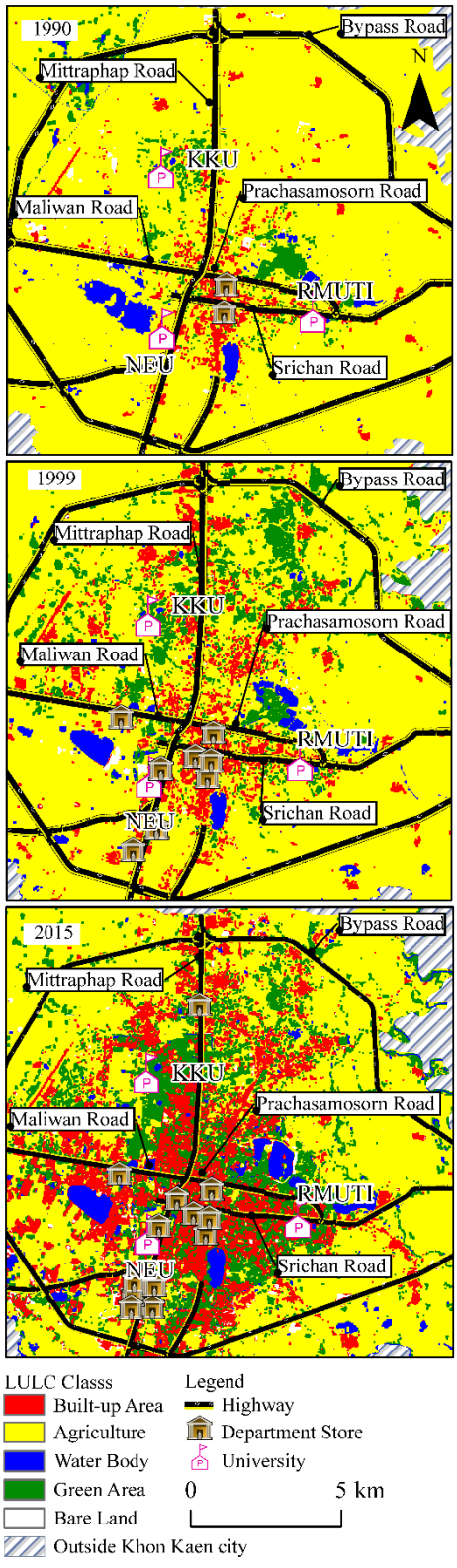

Fig. 8 Location of higher educational institutes, department stores, main road in KKC from 1990 to 2015

By deriving the LULC map in Fig. 8, and from the citizen knowledge from the interviews, it was found that improving the transportation network can facilitate the expansion of the BA class. Furthermore, in the city, there are three main roads, namely, the Maliwan, Srichan, and Prachasamosorn Roads, connecting the eastern and western sides of KKC. These main local roads were built to link the outskirts to the urban area and are a part of the east-west economic corridor between Myanmar and Vietnam [2]. Since the improvement of these three main roads from 1999 to 2015, the BA class rapidly expanded. This behavior is similar to the expansion of the BA class surrounding the Mittraphap superhighway.

Based on the LULC change detection, the landscape fragmentation analysis and the impacts of transportation network of the sub-districts in the G1 and G4 groups (see Fig. 3), it was found that improvements to the road network can be a factor driving the AG class toward the BA class, leading to the expansion of the urban zone in KKC. Furthermore, the spatial connectivity of the road network is also a driving factor that can have a crucial impact on the growth of KKC. However, in the G2 and G3 groups, which are rural sub-districts in the vicinity of the Khon Kaen bypass road, a lower rate of LULC change was found. This result is because as a four-lane road, the KKU bypass road was designed to share traffic with the Mittraphap superhighway. Therefore, the KKU bypass road has been used to serve most of the tractor-trailer trucks. Accordingly, the proposed road network can be a driving factor impacting changes in LULC.

By evaluating education development and road networks to identify the driving factors of LULC change, the analysis revealed that urban sprawl occurred along the transportation network surrounding the three universities. Accordingly, one of the important driving factors is education development, which can impact LULC change by converting the AG class to the BA class.

6. CONCLUSIONS

Using an SVM technique to classify multi-temporal Landsat imagery, a LULC map of KKC consisting of five LULC classes, namely (1) BA, (2) AG, (3) WB, (4) GA, and (5) BL can be derived. The derived LULC map can be used to identify trends in the LULC changes and investigate the factors driving these changes in KKC using change detection analysis together with landscape fragmentation analysis.

The landscape fragmentation analysis indicated that landscape metrics at the class level can be used to detect trends in LULC change. These results were used to categorize ten sub-districts of KKC into four groups, namely, (1) G1, the urban group; (2) G2, the

lowland group; (3) G3, the highlands; and (4) G4, the mixed rangeland group. The landscape metrics for the BA and AG classes in the G1 and G4 groups have demonstrated a trend of urban expansion, whereas those for these classes in the G2 and G3 groups showed low rates of LULC change. The findings indicated that the LULC changes in KKC were mainly driven by the interactions of economic development, education development, population growth and traffic infrastructure.

7. ACKNOWLEDGMENTS

The authors are profoundly grateful for the financial support of the "KKU Scholarship for ASEAN and GMS Countries' Personnel" from Khon Kaen University. Special thanks are given for partial financial support from the Sustainable Infrastructure Research and Development Center (SIRDC) and the Faculty of Engineering, KKU.

8. REFERENCES

[1] Association of Southeast ASIAN Nations, ASEAN Economic Community (AEC). available online at: http://asean.org/asean-economic-community (accessed 10 May 2016), 2015.

[2] Tansukanun P., and Bejarananda B., The Life of Khon Kaen – Cognition or Morphology? Lessons from a Regional City of Thailand, Journal of Mekong Societies, Vol. 8, Issue 1, 2012, pp. 19-46.

[3] Mundia C.N., and Aniya M., Dynamics of Land Use/Cover Changes and Degradation of Nairobi City, Kenya. Land Degradation Development, 17(1), 2006, pp. 97-108.

[4] Kamusoko C., and Aniya M., Land Use/Cover Change and Landscape Fragmentation Analysis in the Bindura District, Zimbabwe. Land Degradation Development, Vol.18, Issue 2, 2007, pp. 221-233.

[5] Wang S.Q., Zheng X.Q., and Zang X.B., Accuracy Assessments of Land Use Change Simulation Based on Markov-cellular Automata model, Procedia Environmental Sciences, Vol. 13, 2012, pp. 1238-1245.

[6] Disperati L. and Virdis S.G.P., Assessment of Land-use and Land-cover Changes from 1965 to 2014 in Tam Giang-Cau Hai Lagoon, Central Vietnam. Applied Geography, Vol. 58, Issue 3, 2015, pp. 48-64.

[7] Horning N., Remote Sensing for Ecology and Conservation: a Handbook of Techniques, 2010, pp. 81- 106.

[8] Schumaker N.H., Using Landscape Indices to Predict Habitat Connectivity, Ecology, 1996, Vol. 77, Issue 4, pp. 1210-1225.

[9] Official Statistics Registration Systems of the Department of Provincial Administration of Thailand: Census Data (in Thai). available online at: http://stat.bora.dopa.go.th/stat/ (accessed 14 January 2016), 2015.

[10] Mountrakis G., Im J., and Ogole C., Support Vector Machines in Remote Sensing: A Review, ISPRS Journal Photogrammetry and Remote Sensing, Vol. 26, Issue 3, 2011, pp. 247-259.

[11] Anderson J.R., Hardy E.E., Roach J.T., and Witmer R.E., A land use and land cover classification system for use with remote sensor data. Geological Survey Professional Report 964, 1976.

[12] National Statistical Office of Ministry of Digital Economy and Society: NI QGDP and GPP (in Thai). available online at http://service.nso.go.th/nso/web/statseries/statseries15.html (accessed 13 March 2016), 2015.