Change Detection of Land Use and Land Cover by Normalized Difference Vegetation Index Differencing in the City of Chiang Mai, THAILAND

Patiya Pattanasak[1]

[1]Department of Geography, Faculty of Education, Ramkhamhaeng University, Bangkok, THAILAND
E-mail: Patiya13@gmail.com

KEYWORDS: Change detection, Normalized Difference Vegetation Index, Land use, Land cover

ABSTRACT: This study of change detection of land use and land cover by normalized difference vegetation index (NDVI) differencing in the city of Chiang Mai, THAILAND aimed to 1) analyze patterns of land use and land cover by NDVI and image classification in the city of Chiang Mai and 2) analyze changes in land use and land cover in the city of Chiang Mai from the year 2000 to 2015. The study of change detection used normalized difference vegetation index differencing and maximum likelihood classification from Landsat 7 ETM+ in year 2000 and Landsat 8 OLI in year 2015. The accuracy assessment used confusion matrix and the changes of land use was based on geographic information systems (GIS).

The study found that land use can be classified into 7 types which were urban areas, paddy field, horticulture, evergreen forest, deciduous forest, forest plantation and water bodies. The greatest change in land use and land cover from 2000 – 2015 was an increase of NDVI of less than 10 percent. The accuracy assessment used total accuracy and kappa statistics. In 2000, the results show total accuracy and kappa statistics of 68.29 percent and 58.74 percent, while in 2015 they were 67.14 and 57.42 percent, respectively. The study found that urban areas and horticultural area increased by 15.21 percent and 2.55 percent. Meanwhile, paddy field, deciduous forest, evergreen forest, forest plantation and water bodies decreased by 10.41, 2.81, 2.58, 0.73 and 0.22 percent, respectively. The most changed areas were paddy field and deciduous forests which had become urban areas with the outward expansion from the center of Chiang Mai city to the surrounding areas.

INTRODUCTION

Currently, land use and land cover in the city of Chiang Mai are changing rapidly. Some sources of data indicating, for example, forest cover, do not correspond to actual conditions of the area. This is due to a shortage of reliable resources, especially high-resolution satellite data. As a result, in past, it was not possible to map all land uses at once. Nowadays, high-resolution satellite imagery is used to document actual land use and land cover, but there are often limitations to near real-time monitoring, particularly in urban areas of Chiang Mai which are changing rapidly from increased population impacts and intensive economic growth (Sangawongse as cited in Sangawongse, 2009, p.178)

The study area was taken as urban of Chiang Mai which has a coverage including Mueng Chiang Mai district and neighboring urban communities. This zone is similar to the study of land use change in Chiang Mai and the surrounding area from LANDSAT 5 TM satellite data in 1991, which showed that there was a general change from degraded forest to low density habitat (Sangawongse, 2009, p.181)

This research has led to development of a remote sensing technique with geographic information systems for use in analyzing land use and land cover changes from LANDSAT 7 ETM + in year 2000 and LANDSAT 8 OLI in year 2015. The study uses a NDVI and Maximum likelihood classification method. Land use changes in the aforementioned period were analyzed by GIS. The results will assist in planning of urban expansion of Chiang Mai city for the future.

OBJECTIVES

1.To analyze patterns of land use and land cover by NDVI and image classification in the city of Chiang Mai.

2.To analyze changes of land use and land cover in the city of Chiang Mai from the period 2000 to 2015.

STUDY AREA

The study area includes the city of Chiang Mai which includes the highly urbanized areas of Mueng Chiang Mai, plus neighboring urban communities in Mae Rim, San Sai, Hang Dong, Sarapi, San kampaeng, San Pa Tong and Doi Saket districts.

MATERIALS AND METHOD

Data

1. LANDSAT 7 ETM+ Satellite images captured in the year 2000 in 8 bands, LANDSAT 8 OLI/TIRS Satellite images captured in 2015 with 11 bands (9 bands of OLI) with resolution of 30 meters in multi-spectral bands from Geo-Informatics and the Space Technology Development Agency (Public organization).
2. Topographic map L7018 sheets 4746 I, 4746 II, 4747 II, 4846 I, 4846 II, 4846 III, 4846 IV, 4847 II, 4847 III.
3. Spatial data in the study area, including administrative boundaries, roads, rivers and land use in years 2000 and 2015.

Data preparation

1. Landsat 8 OLI and Landsat 7 ETM+ which were modified by geometric correction and atmospheric correction (DN to reflectance) (Kiyoshi, 2005)
2. Import of the topographic map to computer.

Geometric correction

This study applied satellite images to map corrections (Jensen, 1996) using topographic maps L7018 for reference. Geometric equation was used with second order polynomials. Error was less than 1 pixel. Resampling used nearest neighbour interpolation.

Atmospheric correction

Calculated reflectance values from satellite data from LANDSAT 7 ETM+ and LANDSAT 8 OLI as follows:

LANDSAT 7 ETM+ Satellite image

Calculated reflectance values from satellite data according to the following equation:

$$L\lambda = \frac{DN}{Gain} + \text{bias} \qquad \text{Equation 1}$$

where

Lλ = Cell value as radiance
DN = Cell value digital number
Gain = Gain value for a spectral band
Bias = Bias value for a spectral band
Then, calculation of radiance to TOA reflectance from the following equation:

$$P\lambda = \frac{\pi \; x \; L\lambda}{ESUN\lambda \; x \; COS(\theta s)} \qquad \text{Equation 2}$$

where

Pλ = Unitless plantary reflectance
Lλ = spectral rediance
ESUNλ = mean solar exoatmospheric irradiances
θS = 90° - solar zenith angle. (Yale university, 2017)

LANDSAT 8 OLI Satellite

$$P\lambda' = M\,pQ\,cal + A\,p \qquad \text{Equation 3}$$

Where

Pλ' = TOA (Top of atmosphere) planetary reflectance, without correction for solar angle.
M p = Band – specific multiplicative rescaling factor from the metadata
A p = Band – specific additive rescaling factor from the metadata
Q cal = Quantized and calibrated standard product pixel value (DN)

Then, correcting the reflectance value with sun angle using the following equation:

$$P\lambda = \frac{P\lambda'}{\cos \theta SZ} \quad \text{or} \quad P\lambda = \frac{P\lambda'}{\sin \theta SE} \qquad \text{Equation 4}$$

where

$P\lambda$ = TOA (Top of atmosphere) planetary reflectance

$P\lambda'$ = TOA (Top of atmosphere) planetary reflectance without correction for solar angle.

θSZ = Local solar zenith angle; $\theta SZ = 90° - \theta SE$

θSE = Local sun elevation angle. (U.S. Geological Survey, 2017)

Data analysis

1. Analysis of NDVI from LANDSAT 7 ETM+ in 2000 and LANDSAT 8 in 2015 using the following equation:

$$NDVI = \frac{\text{Near infrared - Red}}{\text{Near infrared + Red}} \quad \text{(Gao, 2009)} \qquad \text{Equation 5}$$

2. Analysis of change detection of land use and land cover by NDVI differencing in Chiang Mai city from year 2000 to 2015.
3. Analysis of land use and land cover according to the supervised classification by maximum likelihood classification and land use mapping in years 2000 and 2015. Accuracy assessment of image classification used by confusion matrix. Overall accuracy, users' accuracy, producers' accuracy and kappa statistic were used. Kappa statistics can be calculated as equation 6.

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} \cdot x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} \cdot x_{+i})} \quad \text{(Lillesand and Kiefer, 1994)} \qquad \text{Equation 6}$$

4. The change of land use mapping by GIS software.
5. Conclusion of the study.

RESULTS

Analysis of NDVI

LANDSAT satellite images were done by geometric and atmospheric correction. The NDVI can be calculated as shown in figure 1 and figure 2.

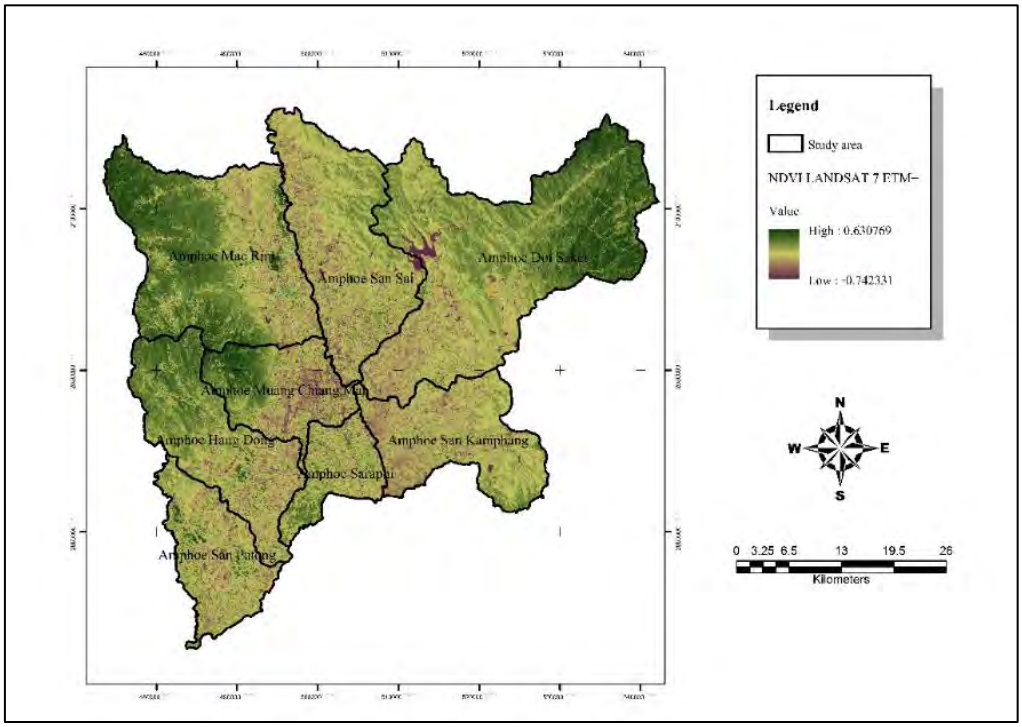

Figure 1 NDVI analyzed from LANDSAT 7 ETM+ in year 2000.

Figure 1 is the analysis of NDVI from LANDSAT 7 ETM + satellite image in the study area in year 2000. NDVI was -0.74 to 0.63. The highest areas of NDVI were found at dry evergreen forests and rainforests on the east which were located in Doi Saket district. Moreover, high levels of NDVI were found at Mae Rim district. On the other hand, Mueng Chiang Mai district had negative values of NDVI which means that there is no vegetation.

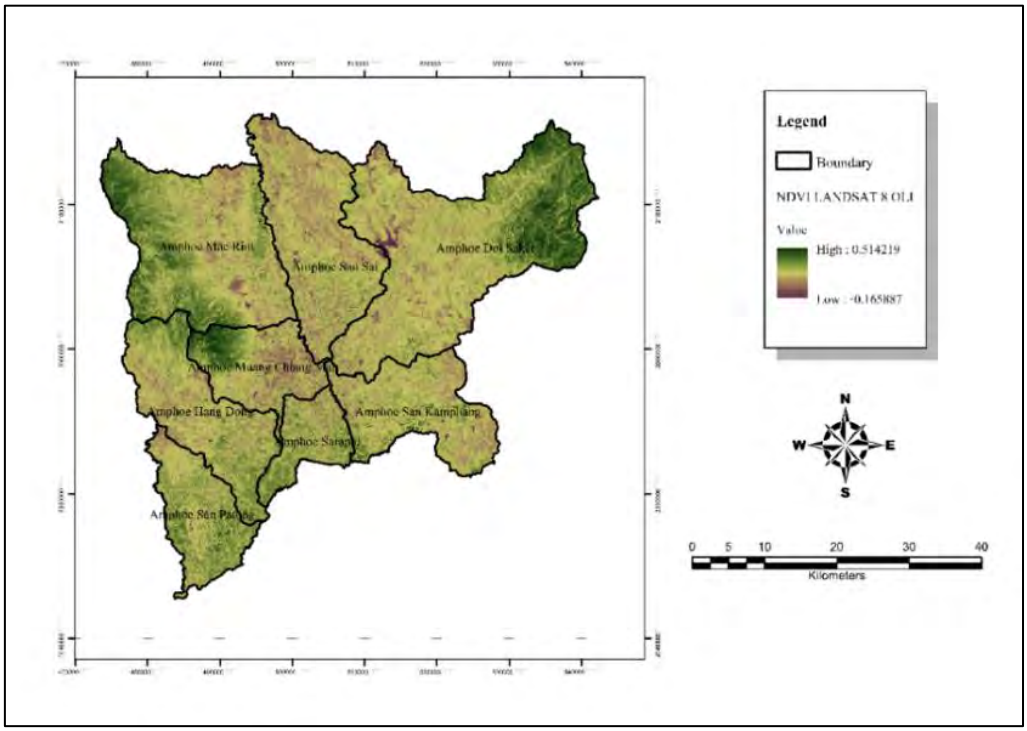

Figure 2 NDVI analyzed from LANDSAT 8 OLI in year 2015.

Figure 2 is the analysis of NDVI from LANDSAT 8 OLI satellite images in the study area in 2015. The NDVI found was -0.166 to 0.514. The highest of NDVI were found at dry evergreen forests and rainforest in the east

which were located in Doi Saket district. Moreover, high levels of NDVI found in Mae Rim district were similar to year 2000.

Change detection of land use and land cover by NDVI differencing during years 2000 – 2015.

The notable features of change detection of NDVI during the year 2000 and 2015 shown in figure 3 and table 1 include a greater than 10% of NDVI and a greater than 10% decrease of NDVI.

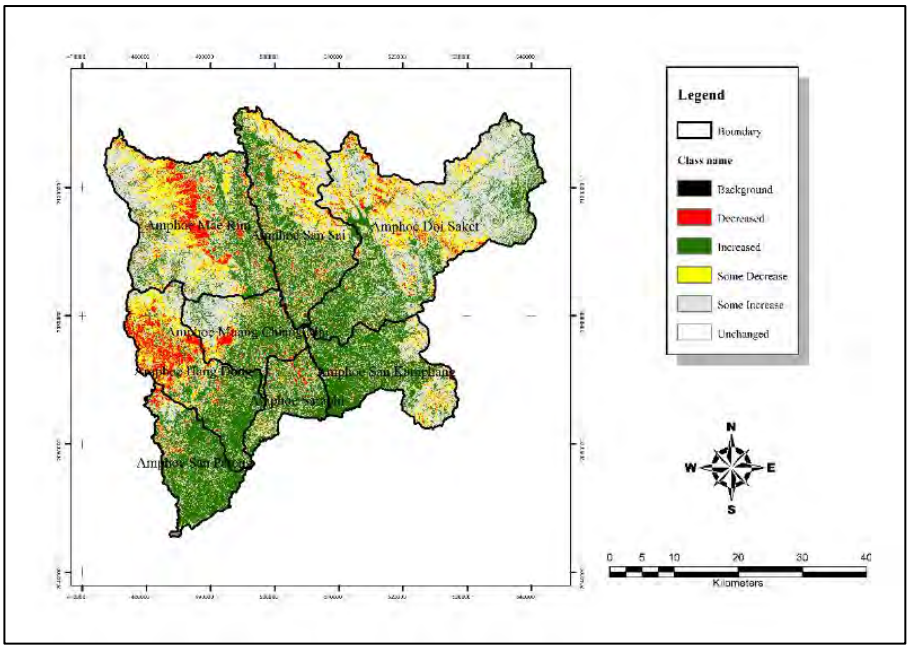

Figure 3 Change detected of land use and land cover by NDVI differencing during the years 2000 – 2015.

Table 1 Change detected of land use and land cover by NDVI differencing.

Land use changed	Number of pixels (resolution 30 meter)	Area (Square kilometer)	Area (Rai)
Greater than 10% decrease of NDVI (red color)	198,098	178.28	111,430.12
Greater not over 10% decrease of NDVI (yellow color)	457,322	411.59	257,243.62
Greater than 10% Increase of NDVI (green color)	959,567	863.61	539,756.43
Greater not over 10% increase of NDVI (grey color)	1,082,338	974.10	608,815.13

The study found an increase of NDVI not over 10%, of 974.10 km^2 (608,815.13 rai) in years 2000 - 2015, covering most of the eastern areas in Doi Saket district and west areas of Mae Rim district. These areas were mostly deciduous forest and evergreen forest.

An increase of 863.61 km^2 (539,756.43 rai) of NDVI over 10% was found covering the central and southern parts of the city of Chiang Mai. Land uses were urban, horticulture and paddy fields, respectively.

Decreases of NDVI not over 10%, of 411.59 km^2 (257,243.62 rai) of NDVI covered parts of Hang Dong district, Mae Rim district, San Sai district, Doi Saket and south of San Kamphaeng. These areas were mostly deciduous forest.

Finally, 178.28 km^2 (111,430.12 rai) of areas of decreased NDVI greater than 10% were found in the west of Chiang Mai city, in Hang Dong district and Mae Rim district. Land use was deciduous forest near residences.

Classification of Land use and Land cover

In this research, the classification of satellite images used the land use classification system of Thailand. Classifications included urban land, agricultural land which were in turn classified as paddy fields, horticulture, and forest area which were classified as deciduous forest, evergreen forest and forest plantation. Finally, water bodies were also included.

The supervised classification from Landsat 7 ETM+ and Landsat 8 OLI by maximum likelihood classification.

The supervised classification from Landsat 7 ETM+ by maximum likelihood classification is shown in figure 4 and Landsat 8 OLI is shown in figure 5. Training sites was selected in each land use more than 700 pixels.

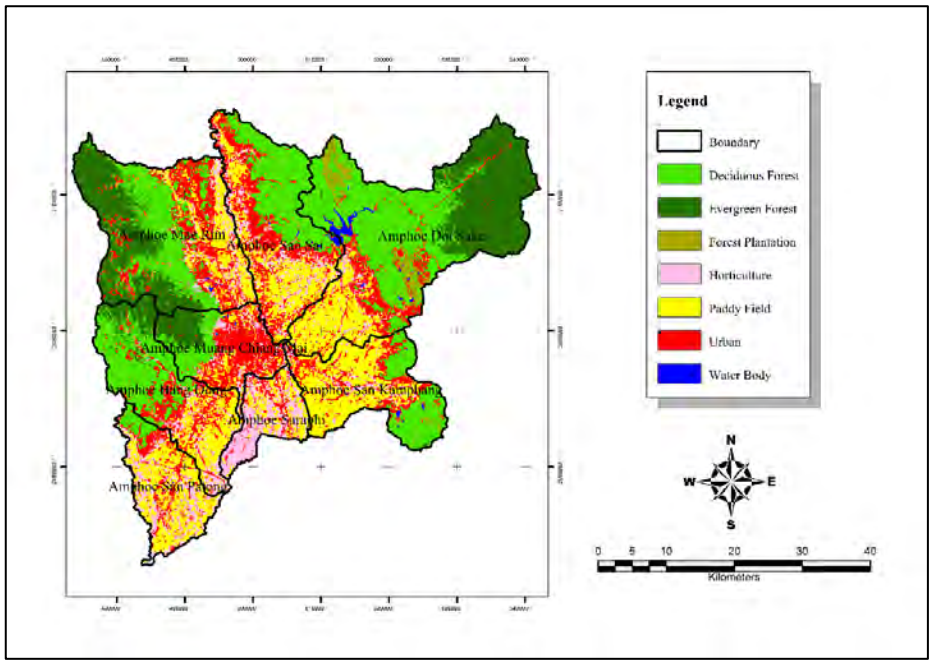

Figure 4 Land use and land cover classification in the city of Chiang Mai in year 2000 from LANDSAT 7 ETM+.

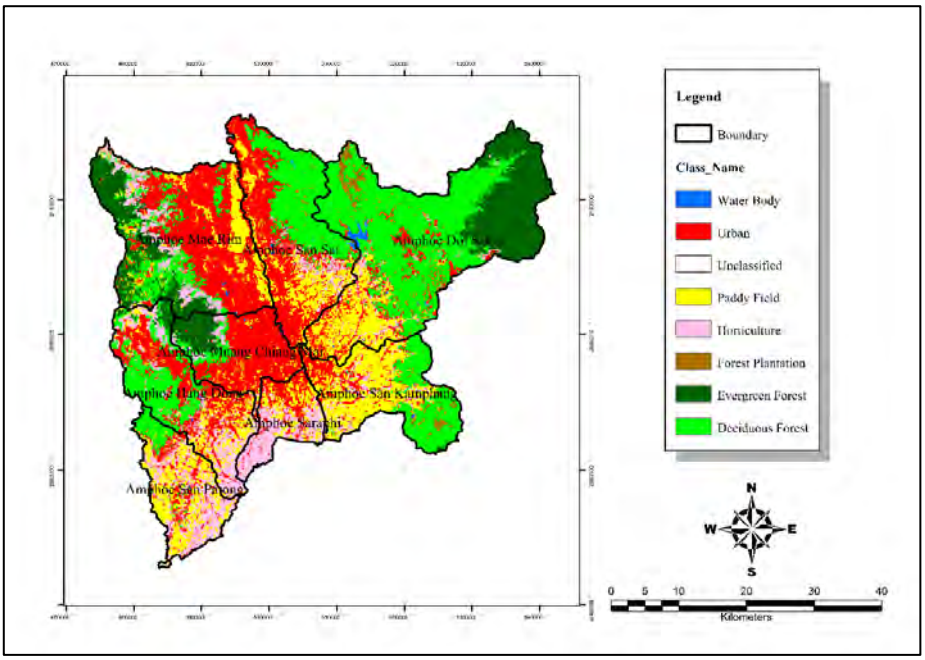

Figure 5 Land use and land cover classification in the city of Chiang Mai in year 2015 from LANDSAT 8 OLI.

Accuracy assessment

The accuracy assessment compared the evaluated map with a reference map and created a confusion matrix for accuracy assessment of the classification which can be seen in tables 2 and table 3.

Table 2 Confusion matrix of image classifications in year 2000

		Class type determined from referenced source								
	Land use/ Land cover	Paddy field	Urban	Forest plantation	Deciduous forest	Evergreen forest	Forest plantation	Water body	Total	Users' accuracy
Class type determine from classified map	Paddy field	55	13	0	1	0	21	2	92	59.78
	Urban	1	23	0	5	0	8	0	37	62.16
	Forest Plantation	0	0	1	2	0	0	0	3	33.34
	Deciduous Forest	0	2	0	107	1	11	1	122	87.70
	Evergreen forest	0	0	0	29	25	4	0	58	43.10
	Forest Plantation	3	7	0	0	0	22	0	32	68.75
	Water body	0	0	0	0	0	0	6	6	100.00
	Total	59	45	1	144	26	66	9	**350**	
Producers' Accuracy		93.22	51.11	100	74.30	96.15	33.34	66.67		Total 68.29

Overall classification accuracy = 68.29 %, Kappa Statistic = 0.5874

Table 3 Confusion matrix of image classification in 2015

		Class type determined from referenced source								
	Land use/ Land cover	Paddy field	Urban	Forest plantation	Deciduous forest	Evergreen forest	Forest plantation	Water body	Total	Users' accuracy
Class type determine from classified map	Paddy field	43	13	0	1	0	7	1	65	66.15
	Urban	4	45	1	21	0	18	0	89	50.56
	Forest plantation	0	0	4	2	0	2	0	8	50.00
	Deciduous forest	0	1	0	100	1	4	0	106	94.34
	Evergreen forest	0	0	0	14	17	4	0	35	48.57
	Forest Plantation	2	6	0	11	2	22	0	43	51.16
	Water body	0	0	0	0	0	0	4	4	100
	Total	49	65	5	149	20	57	5	**350**	
Producers' Accuracy		87.76	69.23	80.00	67.11	85.00	38.60	80.00		Total 67.14

Overall classification accuracy = 67.14%, Kappa Statistic = 0.5742

Analysis of land use and land cover change in the period 2000 – 2015

Analysis of land use and land cover change from year 2000 – 2015 using an overlay technique is shown in figure 6.

As can be seen in figure 6, deciduous forest and horticulture areas changed to urban areas. Change occurred especially in Muang Chiang Mai district and outer areas including Mae Rim, San Sai, San Kamphaeng and Hang Dong districts. Moreover, there was also a change of forest area to horticulture in Sarapi, Hang Dong and Sanpatong districts. The highest of changing area were paddy field to urban area (223.67 km^2). Moreover, the deciduous forest changed to urban area (135.96 km^2). The comparison of each land use are shown in figure 7.

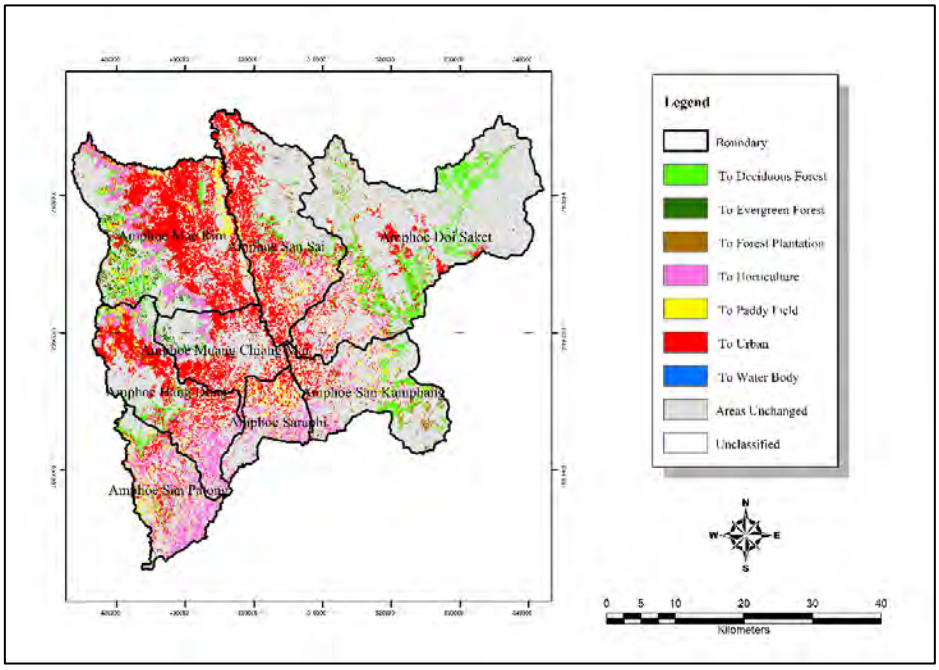

Figure 6 Analysis of land use and land cover change during years 2000 – 2015 in the city of Chiang Mai.

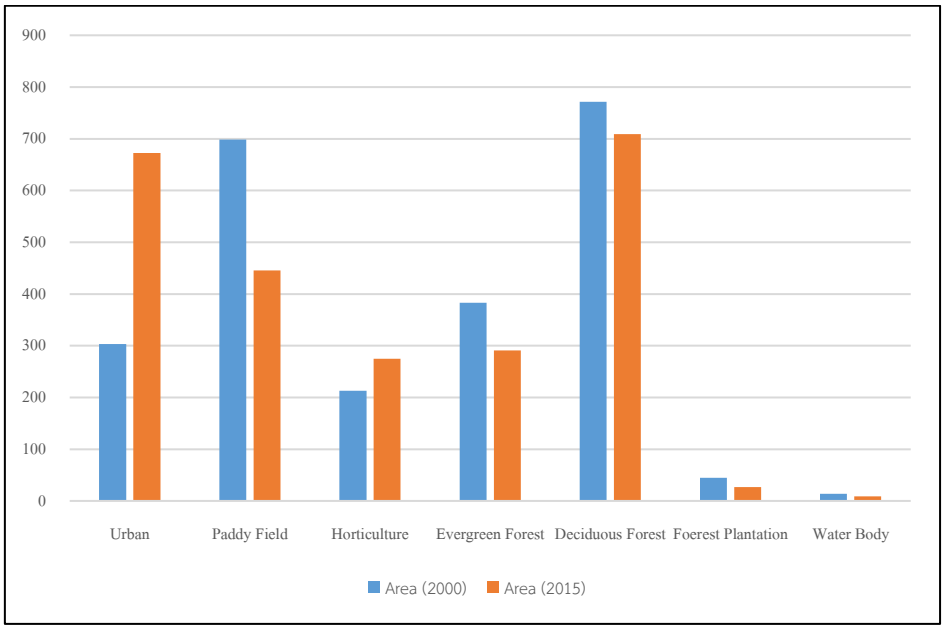

Figure 7 Comparison the changed of land use and land cover in the city of Chiang Mai during years 2000 – 2015.

CONCLUSION

Change detection of Land use and land cover by NDVI differencing in Chiang Mai city from 2000 to 2015 found an increase of NDVI not over 10 percent in an area of 974.10 km^2. In addition, the decrease in NDVI over 10 percent was an area of 178.28 km^2. The study results agree with Sahebjalal and Dashtekian (2013) study of land use and land cover change using NDVI differencing and image classification of Ardakan, Iran. The decrease of NDVI of more than 10% was found in urban areas which have been expanding while forest and agricultural lands are generally decreasing. In the study area, the decrease of NDVI of more than 10% was composed of forest area near residential areas.

Land use and land cover can be classified into7 types. The results from the classification of satellite imagery by maximum likelihood classification in year 2000 showed the deciduous forest covered the greatest area at 771.71 km^2. Meanwhile, water body cover was low at 13.78 km^2. In 2015, deciduous forest area accounted for 709 km^2. This study's results agree with Sangawongse (2009) study of the dynamics of land use in Chiang Mai using remote sensed data and geographic information systems and techniques for modeling urban areas. Their results found that urban

year 2006 and has tended to continue to expand subsequently. Thus, trends of urban expansion are likely to continue to increase, changing from agricultural use to urban areas.

The accuracy assessment for years 2000 and 2015 was performed using a confusion a matrix. Comparison between land use maps of the Land Development Department in years 2009 and 2015 were used as a reference. It was found that the total accuracy and kappa statistics in year 2000 were 68.29% and 58.74%, while in 2015 they were 67.14% and 57.42%, respectively. This represents a moderate level of accuracy and consistency. The study findings agree with Pattanasak (2013) study of analysis of land use patterns from satellite imagery in Mae Rim district in Chiang Mai province. This was a comparative study of object-based analysis and pixel-based classification. The classification results of Thaichote satellite images were compared with land use maps of Land Development Department. The study found that the total accuracy was moderate.

The analysis found that land use change increases were mostly in urban land use (15.21%) and horticulture (2.55%), while areas of decrease were paddy fields (10.41%), evergreen forest (3.81%), deciduous forest (2.58 %), forest plantation (0.73 %), and finally, water bodies (0.22%).

The most changed areas were paddy fields and deciduous forests which had become urban areas with the outward expansion from the center of Chiang Mai to the surrounding areas. Horticultural areas increased from the deciduous forests, especially in the south of Chiang Mai, including Sarapi, Hang Dong and San Pa Tong districts. In addition, the middle of Chiang Mai had changed from forest and paddy field cover to urban area and the western part of the city has changed from forest to urban. Meanwhile, agricultural and horticultural crops were found in the bordering areas of Chiang Mai.

RECOMMENTATIONS

1. Future research of land use should examine at least 3 periods to determine future land use trends.
2. In future research, vegetation indices should use equations which will be accurate in soil and urban areas. The results could be compared with NDVI.
3. Other types of satellite images with high resolution should be used for more complete image classification.

REFERENCES

Gao, J., 2009. Remotely Sensed Imagery. USA: McGrraw-Hill Companies.

Jensen, J. R., 1996. Introductory Digital Image Processing: A Remote Sensing Perspective. 2nd edition. USA: Prentice – Hall.

Kiyoshi, H., 2005. DN to reflectance. Retrieved November 1, 2016, from http://www.rsgis.ait.ac.th/~honda/textbooks/advrs/ DN2Reflectance_2p.pdf.

Lillesand, T.M. & Kiefer, R.W., 1994. Remote Sensing and Image Interpretation. New York: John Wiley & Sons.

Pattanasak, P., 2013. The Analysis of Land Use Patterns by Satellite Image Classification in Mae Rim District, Chiang Mai Province. Ramkhamhaeng Research Journal of Science and Technology. 17(2), pp. 10- 22.

Sahebjalal, E. and Dashtekian, K., 2013. Analysis of land use- land cover changes using normalized difference vegetation index (NDVI) differencing and classification methods. African Journal of Agricultural Research. Retrieved February 29, 2016, from http://www.academicjournals.org/ article/article1380905222_Sahebjalal%20and%20Dashtekian.pdf.

Sangawongse, S., 2009. Remote sensing in using of land use and land cover and application. Bangkok: V. Print (1998) Ltd.

U.S. Geological Survey., 2017. Landsat project description. Retrieved August 13, 2017, from https://landsat.usgs.gov/landsat-project-description.

Yale University., 2017. How to Convert Landsat DNs to Top of Atmosphere (TOA) Reflectance. Retrieved August 13, 2017, from http://yceo.yale.edu/how-convert-landsat-dns-top-atmosphere-toa-reflectance.