INTEGRATED SATELLITE-DERIVED INDICES TO ESTIMATE CHANGE DETECTION OF VEGETATION CANOPY DENSITY IN THE LOWER CHI BASIN, NORTHEAST THAILAND

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ABSTRACT: Riparian forest is an important perceptible ecosystem that preserves the loss of natural filtering of sediment, water quality, wildlife habitat and connectivity with other adjacent landscapes. Agricultural encroachment on the riparian has significant impact on the overall ecosystem of watershed areas. Change detection of the riparian canopy density should be investigated for better management of vegetation within the watershed. This study aims to identify the vegetation canopy density and its spatial distribution, using an integration of satellite-derived indices. The study area, the Lower Chi basin, covers an area of about 277,097.55 ha. and is located in the central part of northeastern Thailand. The Landsat 4 TM and Landsat 8 OLI data acquired on January 22, 1989 and January 6, 2015 covering the study area were used for analysis process. A spatial integration of Vegetation Index (VI), Bare Soil Index (BI) and Shadow Index (SI) was digitally performed and analyzed to classify the Vegetation Canopy Density (VCD). In addition, ground truth investigation of 70 exemplars was conducted to establish the reliability of model used for VCD and land cover and land use types. Regarding the change detection of VCD, the result obtained shows a significant change of the vegetation area and its VCD between 1989-2015. A significant increase of the total area of riparian vegetation was identified. The findings indicate that the area of VCD > 70% increases from 16.49% in 1989 to 35.55% in 2015. The largest fall in the VCD 10-40% area from 1989 to 2015 are 12.89%, accounting for 35,713.03 ha. The total of the increased area of riparian vegetation with high VCD is mainly attributed to an encroaching agriculture. The agreement between the result obtained and the ground observation for the VCD in 2015 is reliably obtained with Kappa coefficient of 0.76. The study model shows advantages in an approach to integrating the indices for vegetation conditions of which the VCD and its land cover land use are clarified for better watershed management.

KEY WORDS: Riparian forest, Vegetation Canopy Density (VCD), Change Detection, Landsat

1. INTRODUCTION

Land Cover Land Use (LCLU) classification, based on satellite data capturing surface condition at an acquisition date, inadequately provides the required information for sustainable management. A problem with the classification of image data is to be able to meaningful understand the complexity of heterogeneous landscape. To better understand the information suitable for the management, VCD is prerequisite to estimate the degree of vegetation depletion of which is unable to extract from LCLU classes. The study area, the Lower Chi Basin (LCB) in Northeast Thailand differs from the upper stream due to stagnant water, periodical flooding, high water condition and unique groups of living organisms found there. The LCB is considered as environmentally sensitive area where its depletion introduces the loss of native plant species, wildlife habitat, natural filtering of sediment, aesthetic qualities and etc. Most of vegetations are a combination of riparian forest, wetland crops, shrub, thicket, bamboo and etc. (Mongkolsawat, 2008). This study was conducted across the Northeast of Thailand using SPOT data acquired during 2005-2007 which provided riparian forest and its setting. In addition, information about the study approach applying NDVI and tree-decision method and the main species of vegetation within sub-watersheds was identified.

Attempts to identify the Forest Canopy Density (FCD) have been made, based on the data derived from an integration of Vegetation Index (VI), Bare Soil Index (BI), Shadow Index (SI) and Thermal Index (TI) and successful applied in a number of countries in tropical region (Rikimura et al., 2002). The mentioned indices are normalized to the same range, the canopy density was computed in percentage for each pixel. Another study conducted a comparison of three classification approaches to estimate FCD of tropical mixed deciduous vegetation (Su Mon et al., 2012). The three classification approaches comprised maximum likelihood classification (MLC), multiple linear regression (MLR) and FCD Mapper. Monitoring tropical deforestation that uses the FCD model prove to be an effective means for measuring forest cover assessment with reliable result and less information of ground validation (Deka et al., 2013). Rikimura et al. (2002) use the FCD model which consists of four factors: vegetation, bare soil thermal and shadow. The application of the similar FCD model was performed in the north of Iran by Saei jamalabad and Abkar (2004), yielding reliable satisfaction. In India the FCD model was used to determine structural and composition of forest stand occurring with the dry deciduous forest succession (Roy et al., 1996). Report on the application of the FCD model in West Java, the forest health can be detected but this approach is unable to resolve the density of two different types of vegetation (Hadi et al., 2004). A combined FCD and ASTER DEM was adopted to study the variation of dense forest in large scale. The FCD was calculated, based on bare soil index, shadow index and vegetation index yielding the overall accuracy of 86 to 90% (Kumar et al., 2015).

As for the study of the environmentally sensitive areas in the LCB where the heterogeneous landscape, including riparian vegetation, wetland ecosystem and agricultural uses found there, not only LCLU types but also its canopy density and composition should be considered to optimize the development of sustainable management. The VCD approach is thus established by an integration of satellite-derived indices with objective of identifying the vegetation canopy density and its spatial distribution. Moreover, the methodology to be obtained enable us to disseminate knowledge on the basis of rapid information available to publics and natural resource manager.

2. STUDY AREA

The emphasis is placed on the Lower Chi basin (15º 9' to 16º 0' N., 103º 36' to 104º 54' E.) in the Northeast of Thailand (Figure1). The study area covers an area of 227,097.55 ha., in the portions of Yasothon, Roi Et, Sisaket and Ubon Ratchathani provinces. The topography is flat to gently undulating, with elevation ranging from 120 to 150 m. above mean sea level. The area receives 5-6 months rainfall from May to October, varied from 1,300 to 1,400 m.m./year (Meteorological Department of Thailand, 2002). The Chi river meanders through many provinces in its journey over 765 km. to its confluence of the Mun river in Ubon Ratchathani. The large floods frequently occur during August to September. The shrub, bush bamboo, thicket and paddy field with scattered trees characterize the Lower Chi basin over which a number of birds and wildlife are normally found. The areas surrounding the Lower Chi basin are partially isolated patches of remnant forest mainly dipterocarp trees, including traditional crops (rice and vegetables). Soils are inherently formed from alluvial complex with a wide range of its textures. Geologically, the Lower Chi basin comprises Cenozoic sediment and thick sequence of Mesozoic sediment, the Formations of which are alluvial deposits of Quaternary and Maha Sarakham (Department of Mineral Resources, 1985).

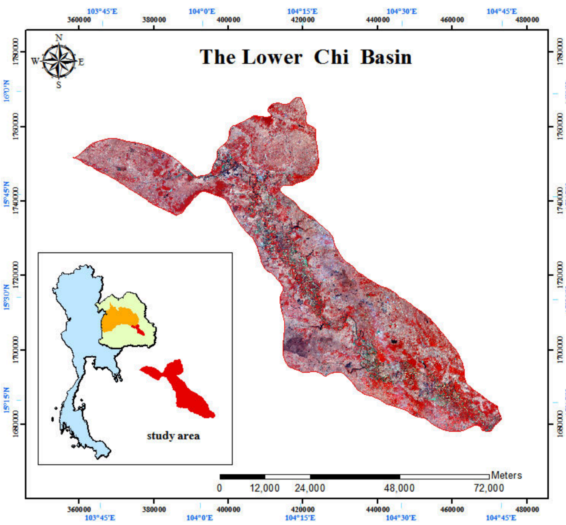


Figure 1 Study area

3. METHODS

This study applies a synergistic approach, in which BI,VI, SI and field observation are integrated to discriminate the VCD. The change detection of VCD during the 1989-2015 is digitally performed to determine its net change. A broad category of LCLU for each of the VCD class is carried out through field observation. Validation of the model is based on a comparison between field-based classes and image-based class.

3.1 Data Sources

Landsat 4 TM and Landsat 8 OLI acquired on January 22, 1989 and January 6, 2015 covering the study area were used. Aerial Orthophotography acquired in 2002 available from Land Development Department was applied as referenced for performing geometric correction and some geographic feature. Topographic map of the Royal Thai Survey Department at the scale 1:50,000 was used for supplement information and ground truth.

3.2 Preprocessing

Both of the Landsat 4 TM and Landsat 8 OLI data transformed to Top of atmosphere (TOA) radiance, based on the USGS Landsat 8 Product (Available online: http://landsat.usgs.gov/Landsat8_Using_Product.php) for further analysis. The satellite data were then geometrically corrected using the aerial orthophotography which geo-referenced to UTM-WGS84 and then nearest neighbor resampling method was applied. To remove the burning areas from water body, the thermal bands were employed. Reason behind this is due to similar spectral response of water in visible and near-infrared bands while that differs in thermal bands. A bitmap mask over the water body was thus digitally executed using strongly absorbed Near-Infrared in a bid to better analysis. A same procedure here below was digitally analyzed for both of two sets of Landsat data (Figure 2).

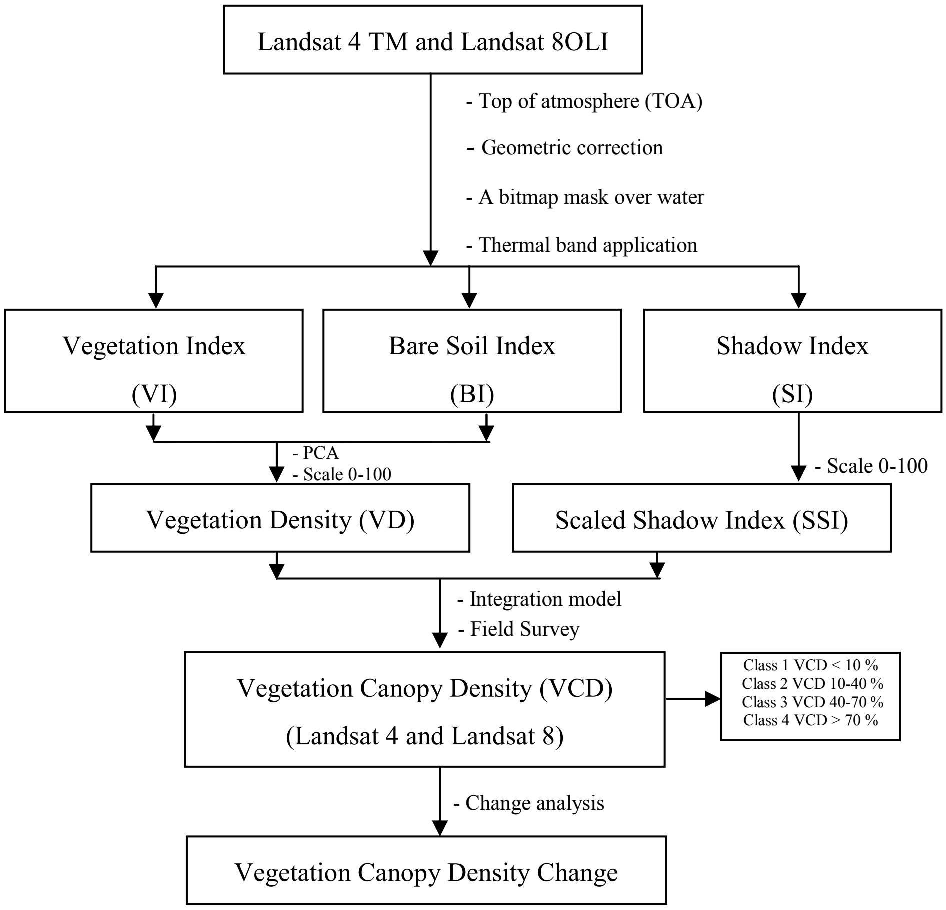


Figure 2 Procedure for Vegetation Canopy Density Model

3.3 Vegetation Canopy Density Model

A combined VD and SI model explained here after is to determine VCD. The VCD model is based on the concept studied by Rikimura et al (2002), integrating vegetation density and scales shadow index. In this study some of indices implemented differ from those of Rikimura model. Details of the model adopted are explained as the following steps.

3.3.1 Vegetation Density (VD)

The indices which capture distinctively a wide range of canopy density are derived from a combination of BI and VI. We used Tasseled Cap transformation (TC) to estimated BI and VI. The TC algorithm used in analysis provides correct coefficients for Landsat 4 and Landsat 8, the calculations are (Crist and Cicone., 1984; Bagi et al., 2014):

For Landsat 4

$$TC1_{(Brightness)} = 0.3037(TM1) + 0.2793(TM2) + 0.4343(TM3) + 0.5585(TM4) + 0.5082(TM5) + 0.1863(TM7) \quad (1)$$

$$TC2_{(Greenness)} = -0.2848(TM1) - 0.2435(TM2) - 0.5436(TM3) + 0.7243(TM4) + 0.0840(TM5) - 0.1800(TM7) \quad (2)$$

where:

TM1:Blue Band (B), TM2:Green Band (G), TM3: Red Band (R), TM4: Near-Infrared Band (NIR1), TM5: Near-Infrared Band (NIR2), TM7: Mid-Infrared Band (IR)

For Landsat 8

$$TC1_{(Brightness)} = 0.3029 (TM2) + 0.2786 (TM3) + 0.4733 (TM4) + 0.5599 (TM5) + 0.508 (TM6) + 0.1872(TM7) \quad (3)$$

$$TC2_{(Greenness)} = -0.2941(TM2) - 0.243(TM3) - 0.5424(TM4) + 0.7276(TM5) + 0.0713(TM6) - 0.1608(TM7) \quad (4)$$

where:

TM2:Blue Band (B), TM3:Green Band(G), TM4: Red Band (R), TM5: Near-Infrared Band (NIR), TM6: Short Wavelength Infrared Band (SWIR1), TM7: Short Wavelength Infrared Band (SWIR2)

The principal component analysis (PCA) was calculated based on the input of TC_1 (BI) and TC2 (VI). The VD can be gathered from the first component1 (PC_1) of the PCA and the PC_1 was then normalized to the range of 0 to 100. The PC_1 generated was converted to an equal interval and assigned as vegetation density of four classes with varied percentage (Figure3).

The fourth interval of the PC_1 characterizes the greater value of VI and lower BI is assigned as the highest VD and identified as dense vegetation. On the contrary, in the case of lower VD value which is attributed to greater BI with much less VI values then such a combined value is set as bare soil. The second and third intervals of the PC_1 value set as slight and moderate VD classes.

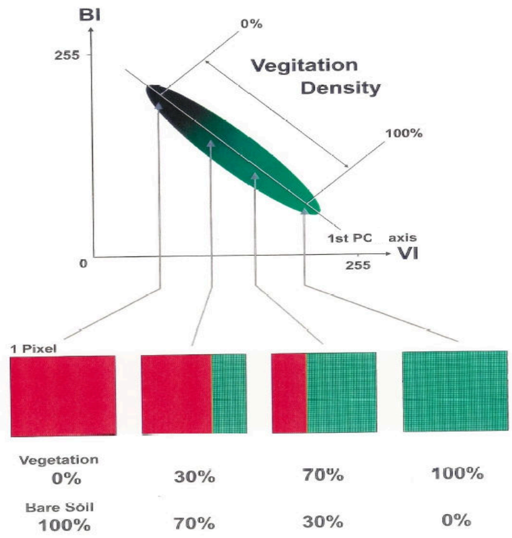


Figure 3 Vegetation Density Model

3.3.2 Scaled Shadow Index (SSI)

Shadow Index (SI)

The SI was generated and used for identifying SSI. The formula for computing the SI is as follows (Rikimura et al., 2002):

For Landsat 4

$$SI = ((256\text{-}TM1)(256\text{-}TM2)(256\text{-}TM3))^{1/3} \tag{5}$$

For Landsat 8

$$S\ I = ((256\text{-}TM2)(256\text{-}TM3)(256\text{-}TM4))^{1/3} \tag{6}$$

The SSI can be produced by rescaling the SI in the range 0 to100.

3.3.3 Vegetation Canopy Density (VCD)

To create the VCD the following formula, combining the VD and SSI is used (Rikimura et al., 2002):

$$VCD = VD(SSI + 1)^{1/2} - 1 \tag{7}$$

An equal interval of the VCD values produced was then classified into four classes. The four classes set as <10, 10-40, 40-70 and >70% VCD for class 1, class 2, class 3 and class 4 respectively. The two-date classified VCD of Landsat 4 and Landsat 8 designated as image sets for data input in an overlay operation by which a union logic model was applied, yielding the VCD change detection.

3.4 Validation

Seventy exemplars of ground truth through field survey for identification of the VCD, LCLU and relevant locational information were conducted based on the Landsat 8 imagery. The distribution of the exemplars is depicted in Figure 4. Each of the exemplars covers at least 2 ha. for the field observation. The result to be obtained uses to establish a cross-tabulation to compare the field-based classes and image-based class for validation by which the kappa statistic was applied.

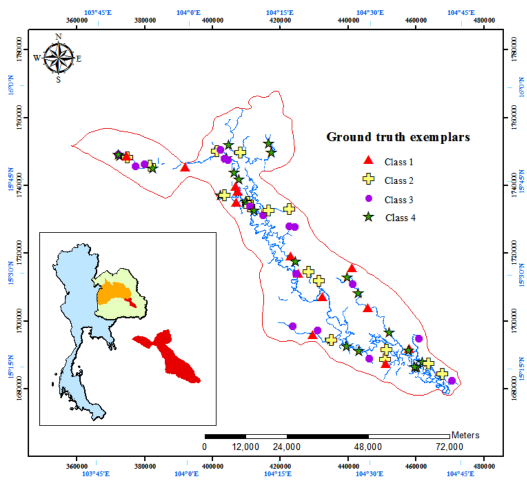


Figure 4 Ground truth exemplars

4. RESULTS AND DISCUSSIONS

4.1 Vegetation Density

The linear transformation performed results in eigenvectors to generate the PC_1 for Landsat 4 and Landsat 8 with eigenvalues of 90.16% and 86.90% respectively, the calculations are:
For Landsat 4

$$VD_{(PC1)} = -0.99551(BI)-0.09470(VI) \tag{8}$$

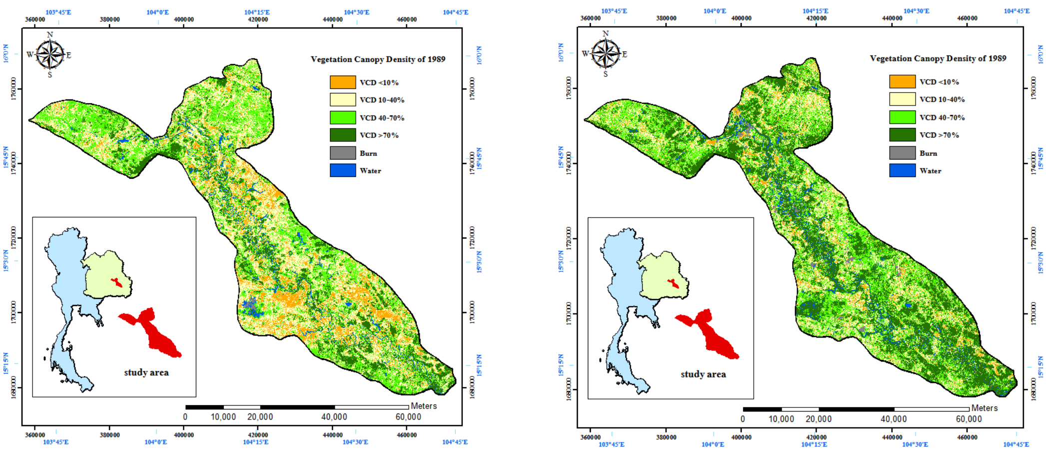
For Landsat 8

$$VD_{(PC1)} = -0.99966(BI)-0.02617(VI) \tag{9}$$

The obtained VD for both of them provided for input in creating the VCD calculation.

4.2 Vegetation Canopy Density Change Detection

A comparison in spatial distribution of VCD between 1989 and 2015 resulting from the classification is shown in Figure 5a and Figure 5b. Variability in water conditions as affected by river stage is the most important factor sorting the group of vegetation types and its VCD. Their setting includes the upper terrace, lower terrace, floodplain and stream bank. The VCD in 1989 was characterized by more apparent in class 1 and class 2 than those in 2015. The class 1 and class 2 distributed mainly over the upper terrace, lower terrace and floodplain. A pattern of increasing area of the class 4 from 1989 to 2015 is evident with the trend of encroaching agriculture on native riparian vegetation (Figure 6). The class 2 for 1989 and the class 4 for 2015 occupied a high proportion of the total area accounting for 35.99% and 35.55% respectively. In terms of the area changes, the fall in bare land from 1989 to 2015 is significant with intensified agricultural uses. The class 3 remains almost unchanged in which change in location is realized.



(a) (b)

Figure 5 (a)Vegetation Canopy Density in 1989, (b) Vegetation Canopy Density in 2015

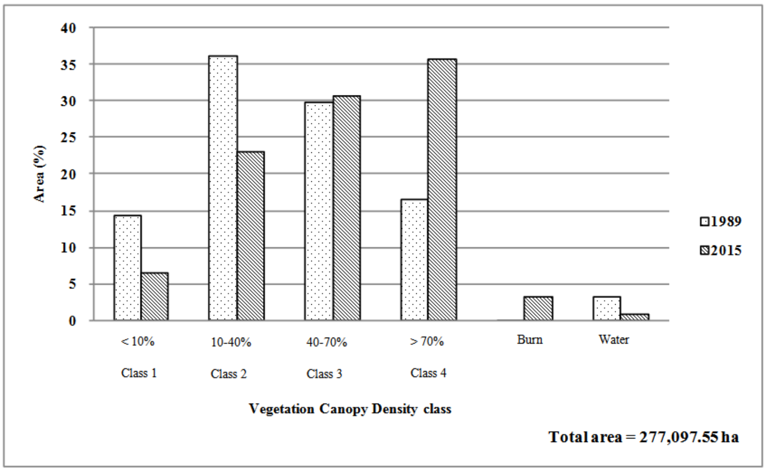


Figure 6 Vegetation Canopy Density in the Lower Chi basin between 1989 and 2015

Table 1 The Vegetation Canopy Density and Landcover/Landuse change between 1989 and 2015

Vegetation Canopy Density Change	Area (ha)	Area (%)	LCLUC 1989	LCLUC 2015
Class 1 1989 and 2015 (No Change)	6157.32	2.22	1	1
Class 1 1989, Class 2 2015	14243.64	5.14	1	2
Class 1 1989, Class 3 2015	11629.91	4.20	1	3
Class 1 1989, Class 4 2015	6147.97	2.22	1	4
Class 1 in 1989, Water 2015	910.95	0.33	1	W
Class 1 1989, Burn 2015	719.04	0.26	1	B
Class 2 1989, Class 1 2015	8581.44	3.10	2	1
Class 2 1989 and 2015 (No Change)	32492.91	11.73	2	2
Class 2 1989, Class 3 2015	35127.24	12.68	2	3
Class 2 1989, Class 4 2015	20740.32	7.48	2	4
Class 2 1989, Water 2015	1396.37	0.50	2	W
Class 2 1989, Burn 2015	1388.99	0.50	2	B
Class 3 1989, Class 1 2015	2665.48	0.96	3	1
Class 3 1989, Class 2 2015	15002.35	5.41	3	2
Class 3 1989 and 2015 (No Change)	30993.51	11.19	3	3
Class 3 1989, Class 4 2015	32054.84	11.57	3	4
Class 3 1989, Water 2015	1113.92	0.40	3	W
Class 3 1989, Burn 2015	296.19	0.11	3	B
Class 4 1989, Class 1 2015	491.86	0.18	4	1
Class 4 1989, Class 2 2015	1778.00	0.64	4	2
Class 4 1989, Class 3 2015	5777.01	2.08	4	3
Class 4 1989 and 2015 (No Change)	36269.51	13.09	4	4
Class 4 1989, Water 2015	1347.24	0.49	4	W
Class 4 1989, Burn 2015	31.68	0.01	4	B
Burn 1989, Class 1 2015	19.08	0.01	B	1
Burn 1989, Class 2 2015	67.86	0.02	B	2
Burn 1989, Class 3 2015	140.04	0.05	B	3
Burn, 1989, Class 4 2015	449.99	0.16	B	4
Burn 1989, Water 2015	42.48	0.02	B	W
Burn 1989 and 2015 (No Change)	16.38	0.01	B	B
Water 1989, Class 1 2015	394.13	0.14	W	1
Water 1989, Class 2 2015	429.49	0.15	W	2
Water 1989, Class 3 2015	875.03	0.32	W	3
Water 1989, Class 4 2015	2855.24	1.03	W	4
Water 1989 and 2015 (No Change)	4378.17	1.58	W	W
Water 1989, Burn 2015	72.00	0.03	W	B
			Total area = 277,097.55 ha	

1= Bare land (Paddy) 2= Grazing or Paddy 3=Moderately dense vegetation (Remnant forest/Shrub/Thicket)
4= Dense vegetation (Evergreen forest/Rubber tree/Shrub)

The LCLUC by type for the different Vegetation Canopy Density percentage in the 2015 is shown in Table 1. The locational LCLU area unchanged from 1989 to 2015 is equivalent to 11.73, 11.19 and 13.09% for the class 2, 3 and 4 respectively. The most obvious LCLUC in area, the class 2 in 1989 to the class 3 in 2015 occupied an area of 12.68%. In addition, changes in 1989 to water body in 2015 was found, accounting for 1.74%. No significant change of the LCLU unchanged class is also found. Spatial distribution of The VCD change is shown in Figure 7, based on the overlay operation between the VCD class in 1989 and 2015.

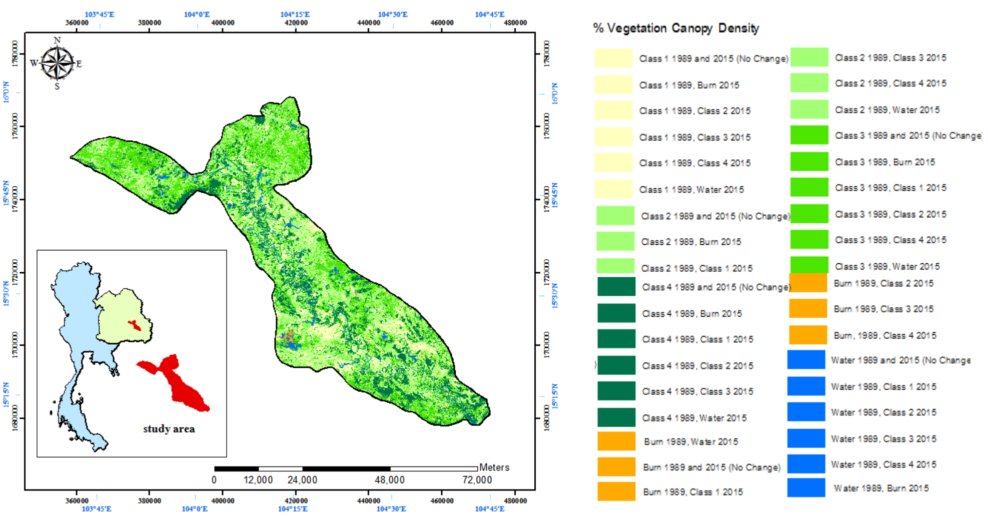


Figure 7 Spatial distribution of The Vegetation Canopy Density between 1989 and 2015

(a) Paddy field

(b) Shrub and Thicket

(c) Rubber tree

(d) Dense vegetation

Figure 8 LCLU types as observed in the field. (a) Paddy field, (b) Shrub and Thicket, (c) Rubber tree, (d) Dense vegetation

The mixture of a wide variety of plants, including shrub, thicket, rubber tree, orchard, bamboo, fast growing tree, exotic tree, perennial and etc. characterizes the riparian vegetation in the Lower Chi basin. The characteristic of those plants can be indicative of both plant function and LCLU intensity, providing an understanding of relationships between river stage/land types with the ecosystem at broader spatial scale. The remnant native vegetations found in the field are clues to understand the extent of its conversion to exotic plant and traditional crops that form heterogeneous current landscapes (Figure 8).

Table 2 Confusion between ground truths and the 2015 map obtained.

Map	**Ground truth**					**User's Accuracy (%)**
	Class 1	Class 2	Class 3	Class 4	Total	
Class 1	12	1	0	0	13	92.30
Class 2	1	13	4	0	18	72.22
Class 3	0	2	12	3	17	70.58
Class 4	0	0	1	21	22	95.45
Total	**13**	**16**	**17**	**24**	**70**	
Producer's Accuracy (%)	93.30	81.25	70.58	87.50		

Overall Accuracy 82.85%
Kappa coefficient of 0.76

As for the validation of the result, the confusion between ground truths of 70 locations and the classified VCD based on the 2015 Landsat 8 imagery in Table 2 shows the agreement between the classes. It indicates overall accuracy of 82.85% with kappa coefficient 0.76. The procedure and user accuracy of VCD were also found in table 2. The classification result is reliably satisfactory.

The VCD model established even though satisfactory result, may be less perfect as is attributed to the LCLU interpretation back to that of 1989 from a combined remnant vegetation and satellite data. Numerous factors and complexity of the landscape likely contribute to introduce the understandings.

5. CONCLUSIONS

The overall increase of the high VCD is apparently observed in 2015, as a result of introduction of fast growing trees and rubber tree while loss of native vegetations found. The findings indicate that the VCD class 4 increases from 16.49% in 1989 to 35.55% in 2015. The largest fall in the VCD class 2 in 1989 to 2015 are 12.89%, accounting for 35,713.03 ha. Both VCD and LCLU types remained unchanged are significant for the class 2, class 3 and class 4. The encroaching cash crops, rubber trees and fast-growing tree on ecological native vegetation in together with urbanization are remarkable trends. Establishment of GIS database provided spatial distribution of vegetation adjacent to river and its tributaries which can be visually displayed. In addition, in each of the VCD classes the inventory of LCLU types and its changes was carried out. Difficulties in discrimination of the vegetation mixture in relation to its setting were found. For further study emphasis should be placed on the model makers and relationships between plant species and its setting or geomorphology.

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