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Estimating Vegetation Canopy Density in the Lower Chi Basin, Northeast, Thailand Using Landsat Data

Supunnee Pladsrichuay[1], Rasamee Suwanwerakamtorn[1] and Nattadon Pannucharoenwong[2*]

[1]Department of Computer Science Faculty of Science, Khon Kaen University, 40002 Thailand.
[2]Department of Mechanical Engineering, Faculty of Engineering, Thammasat University, 12120 Thailand.

Abstract

This study aims to determine the vegetation canopy density (VCD) and classify the information of diverse vegetation species in the Lower Chi basin which covers an approximate area of 277,097.55 ha and is located in the Northeast of Thailand. The integration of the vegetation index (VI), bare soil index (BI) and shadow index (SI) were digitally performed and analyzed to classify the vegetation canopy Density (VCD). Additionally, ground survey was used to study the biodiversity of vegetation species, and establish the reliability of the model used for VCD, land cover and land use types. The results show that the riparian vegetation was classified in terms of aquatic areas, stream banks, and terrestrial zones. The result of the VCD related to the ground survey and the result of this survey show that 13, 18 and 14 the vegetation species are found in the aquatic areas, stream banks, and terrestrial zones, respectively. Remote sensing data and ground survey are increasingly being used to investigate and determine the tree classification in the riparian forest.

Keywords: Vegetation Canopy Density (VCD); Riparian Forest; Northeast Thailand; Landsat 8 OLI

INTRODUCTION

Riparian forests (RF), defined as the zone of interaction between terrestrial and aquatic areas, usually have the greatest importance for biodiversity and biogeochemistry in both the terrestrial and aquatic ecosystems [1-3]. The RF areas would include flood plains, stream banks, and lake zones [3]. These areas are the important habitats for a large number of the vegetation or forest species including the common and rare species that depend on water, nutrients, sediments, and types of soil [4-5]. The riparian forest buffer plays an important role in improving the water quality by filtering sediments and pesticides, enhancing aquatic and wildlife habitats, and providing income opportunities for biodiversity of flora and fauna [6-7]. Forest Canopy Density (FCD) model is an important factor and indicator for making an estimate of the forest canopy density of the vegetation or forest status using satellite imagery [8-10]. The FCD model comprises bio-physical phenomenon modeling and analysis utilizing data derived from four indices: Advanced Vegetation Index (AVI), Bare Soil Index (BI), shadow Index or scaled Shadow Index (SI, SSI), and Thermal Index (TI). It determines the FCD by modeling operation and obtaining the results from these indices. The canopy density is calculated as a percentage of each pixel. The FCD model requires less information of ground investigation. Consequently, it also becomes possible to monitor transformation of forest conditions over time such as the progress of forestry activities [10]. The remote sensing has become an essential tool for monitoring broad-scales of land cover land use (LCLU), and has been developed for detecting LCLU changes [11-12]. The LCLU datasets at a global scale have been developed with high resolution ranging from 300 m to 1 km, using the resolution satellite imagery such as AVHRR, MODIS and MERIS [13-14]. Integrating high-spatial-resolution canopy height model data and satellite images with diverse spectral information could further enrich the spectral signatures and spatial texture data specific to individual tree species and therefore obtain a higher potential accuracy rate in overstorey-canopy species mapping [15]. Therefore, the vegetation canopy density (VCD) model was used to determine the satellite-derived indices with objective of classifying and distribution of plant in the study area using field observation.

METHODOLOGY

The determination of vegetation index (VI), bare soil Index (BI), shadow index (SI), and field observations were analyzed to classify the vegetation canopy density (VCD). The land covers land use (LCLU) data of each VCD class were collected and carried out by map and field surveys. The model validation was based on a comparison between image-based class and field-based classes as described by Pladsrichuay and Mongkolsawat [16].

1. Study area

The study area, which is an area of 227,097.55 ha, is located in the Lower Chi basin (15º 9' to 16º 0' N., 103º 36' to 104º 54' E.) in the Northeast of Thailand as shown in Figure 1. It covers Yasothon, Roi Et, Sisaket and Ubon Ratchathani provinces. The average rainfall varies from 1,300 to 1,400 mm in the Northeast [Meteorological Department of Thailand] during the rainy season (May to October). In the surrounding areas of the Lower Chi basin Shrub, thicket, bush bamboo, as well as paddy fields covered with trees especially dipterocarp trees are commonly found alongside with other birds, and wildlife. There are various soil textures such as the terrace deposits with gravel, and silt and clay. The Lower Chi Basin comprises Cenozoic sediment and thick layers of Mesozoic sediment, which are alluvial deposits of Quaternary and Maha Sarakham [17].

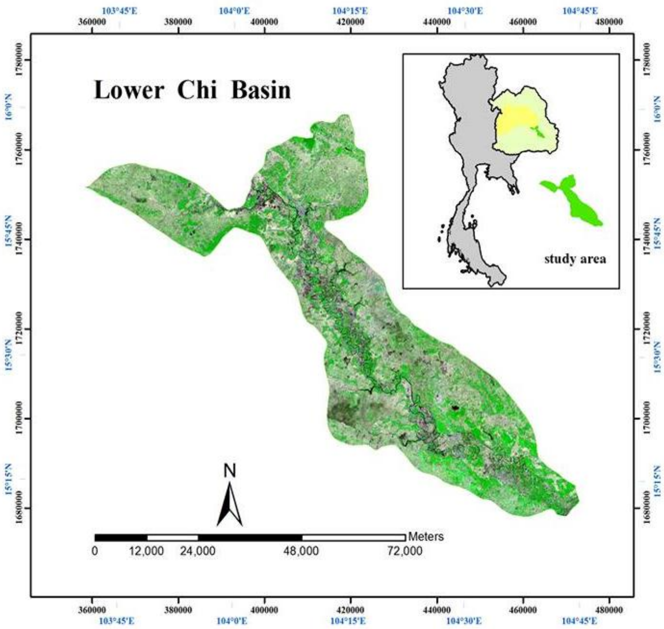

Figure 1. The location of study area in the Lower Chi basin, Northeast, Thailand

2. Data sources

Landsat 8 OLI acquired on January 6, 2015 covering the study area was used. Aerial Orthophotography acquired in 2002 provided by the Land Development Department was applied, as cited above, in order to perform geometric correction and some geographic features. The topographic map drawn by the Royal Thai Survey Department on a scale of 1:50,000 was used as supplement information and ground truth [16].

3. Preprocessing

The Landsat 8 OLI data transformed to Top of atmosphere (TOA) radiance using the USGS Landsat 8 product for determination. The satellite data were corrected by using the aerial ortho-photography which geo-referenced to UTMWGS84, and the nearest neighbor resampling method was then applied. To remove the burning areas from water body, the thermal bands were employed. The 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. The same procedure as seen below was digitally analyzed for both two sets of Landsat data (Fig. 2).

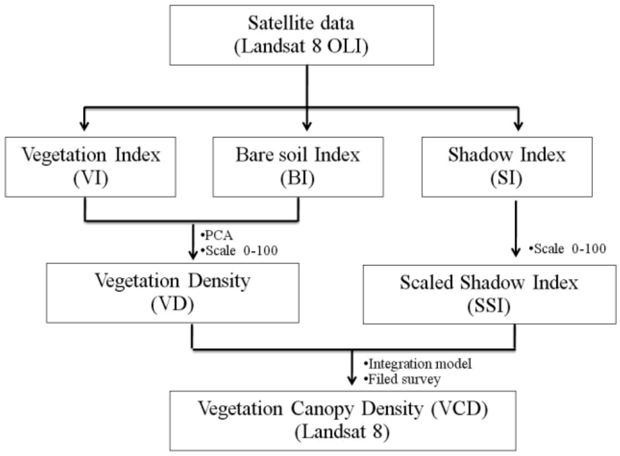

Figure 2. Procedure for vegetation canopy density (VCD) model

4. Vegetation canopy density model

The VD and SI combination model was used to determine VCD based on the concept described in Rikimura et al. [10]. The vegetation density and scales shadow index were determined. Additionally, the model details are interpreted as the following concepts.

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 estimate BI and VI. The TC algorithm used in the analysis provides correct coefficients for Landsat 8 [18], and the calculations are as follows:

$$TC1_{(Brightness)} = 0.3029(TM2) + 0.2786(TM3) + 0.4733(TM4) + 0.5599(TM5) + 0.508(TM6) + 0.1872(TM7) \quad (1)$$

$$TC2_{(Greenness)} = -0.2941(TM2) - 0.243(TM3) - 0.5424(TM4) + 0.7276(TM5) + 0.0713(TM6) - 0.1608(TM7) \quad (2)$$

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)

Scaled Shadow Index (SSI)

The Shadow Index (SI) was generated and used for identifying SSI. The formula for computing the SI is as follows [10]:

$$SI = ((256\text{-}TM2)(256\text{-}TM3)(256\text{-}TM4))1/3 \quad (3)$$

The SSI can be produced by rescaling the SI in the range 0 to 100.

Vegetation Canopy Density (VCD)

To create the VCD the following formula, combining the VD and SSI is used [10]:

$$VCD = VD(SSI + 1)^{1/2} - 1 \quad (4)$$

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.

RESULTS AND DISCUSSION

1. Vegetation Density

The linear transformation performed results in eigenvectors to generate the PC1 for Landsat 8 with Eigen values of 90.16% and 86.90% respectively, the calculations of Landsat 8 is

$$VD\ (PC1) = -0.99966(BI) - 0.02617(VI) \quad (5)$$

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

2. Vegetation Canopy Density

The spatial distribution of VCD in 2015 was shown in Figure 3. 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, flood plain and stream bank. 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 is evident in the trend of encroaching agriculture on native riparian vegetation. The class 4 for 2015 occupied a high proportion of the total area accounting for 35.55%. The class 3 remains almost unchanged in which change in location is realized.

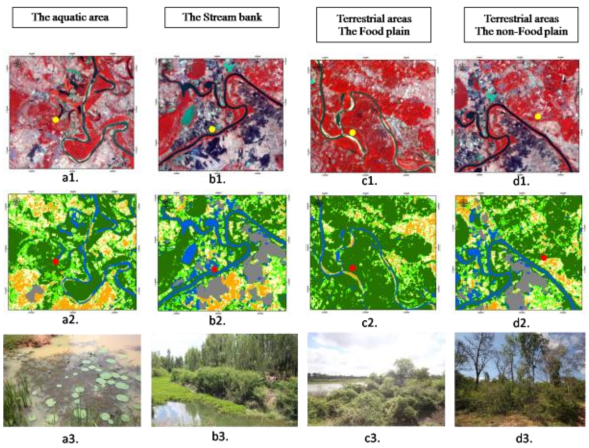

Figure 3. Showing the vegetation cover according to the Landsat 8 image in the study area. a1-a3; the aquatic areas, b1-b3; the stream banks, c1-c3; the terrestrial areas of the food plain and d1-d3; the terrestrial areas of the non-food plain

3. Riparian forest areas

The riparian forest in the Northeast covers an approximate area of 1,261.06 sq. km. of the Chi River. The LCLUC by type for the different Vegetation Canopy Density percentage in the 2015 is shown in Table 1. From the result of this studied, the sub-watershed of the Northeast having abundant and diverse riparian vegetation was showed.

Table 1 the vegetation canopy density and land cover and land use in 2015

Vegetation Canopy Density	Area (ha)	Area (%)
Class 1_L8	18,309.31	6.61
Class 2_L8	64,014.24	23.10
Class 3_L8	84,542.74	30.51
Class 4_L8	98,517.87	35.55
Water_L8	9,189.12	3.32
Burn_L8	2,524.28	0.91
Total	**277,097.55**	**100.00**

Class 1 VCD <10%

Class 2 VCD 10-40%

Class 3 VCD 40-70%

Class 4 VCD >70%

Class 5 Water

Class 6 Burn

4. Vegetation types

Variation in water content affected by river stage is the most important factor sorting the groups of vegetation. The vegetation in the riparian areas was therefore identified in terms of their setting: aquatic areas, stream banks and terrestrial areas.

The vegetation in the riparian area is divided into aquatic areas, stream banks, flood plain and non-flood plain zones. The vegetation species in the aquatic area zone include *Neptunia oleracea* Lour., *Salvinia cucullata* Roxb.ex Bory, *Nymphoides indica* (L.) Kuntze, *Nymphaea nouchali* Burm. f., *Nymphaea lotus* L., *Nelumbo nucifera* Gaertn., *Eichhornia crassipes* (C. Mart.) Solms, *Ipomoea aquatic* Forssk., *Marsilea crenata* C. Presl, *Ludwigia adscendens* (L.) H.Hara, *Vallisneria spiralis* L., *Ceratophyllum demersum* L., and *Hydrilla verticillata* (L. f.) Royle.

The species in the stream bank zone include *Careya arborea* Roxb., *Mitragyna diversifolia* (Wall. ex G. Don) Havil., *Telosma cordata* (Burm. f.) Merr., *Streblus asper*, *Tephrosia purpurea* (L.) Pers., *Albizia lebbeckoides* (DC.) Benth., *Albizia saman* (Jacq.) Merr., *Xanthophyllum* *lanceatum* J. J. Sm., *Vernonia elliptica* DC., *Bambusa bambos* (L.) Voss, *Mimosa pigra* L., *Dipterocarpus alatus* Roxb. ex G. Don, *Praxelis clematidea* R.M.King & H.Rob., *Chromolaena odorata*(L.) King & Robinson, *Panicum incomtum* Trin., *Imperata cylindrica* (L.) Raeusch., *Heliotropium indicum* L., and *Leersia hexandra* Sw.

The terrestrial areas have two groups of vegetation according to their settings: flood plain vegetation and non-flood plain vegetation. The vegetation species in flood plain are *Cyperus stoloniferus* Retz., *Actinoscirpus grossus* (L. f.) Goetgh. & D. A. Simpson, *Cyperus pilosus* Vahl., *Eclipta prostrata* (L.) L., *Phyllanthus reticulatus* Poir., *Flueggea virosa* (Roxb. ex Willd.) Voigt, *Saccharum arundinaceum* Retz., *Mallotus* sp., *Grangea maderaspatana* (L.) Poir., *Brachiaria mutica* (Forssk.) Stapf, *Bauhinia saccocalyx* Pierre, *Sphaeranthus africanus* L., *Calamus* sp., and *Polygonum tomentosum* Willd.

The main species in non-flood plain are *Scoparia dulcis* Linn., *Leucaena leucocephala* (Lam.) de Wit, *Pavetta indica* L. var. tomentosa (Roxb. ex Sm.) Hook. f., *Senna timoriensis* (DC.) H. S. Irwin & Barneby, *Combretum trifoliatum* Vent., *Carallia brachiata* (Lour.) Merr., *Dillenia ovata* Wall. ex Hook. f. & Thomson, *Cratoxylum formosum* (Jacq.) Benth. & Hook.f., *Shorea obtusa* Wall. ex Blume, *Butea monosperma* (Lam.) Taub., *Olax psittacorum* (Lam.) Vahl, *Croton oblongifolius* Roxb., *Memecylon edule* Roxb., *Parinari anamensis* Hance, *Kopsia arborea* Blume, *Zizyphus mauritiana* Lamk., *Pithecellobium dulce* (Roxb.) Benth., *Buchanania lanzan* Spreng., *Litsea glutinosa* (Lour.) C.B.Rob., *Shorea siamensis* Miq., *Corypha lecomtei* Becc. ex Lecomte, *Melodorum fruticosum* Lour., *Diospyros filipendula* Pierre ex Lecomte, *Catunaregam tomentosa* (Blume ex DC.) Tirveng., *Willughbeia edulis* Roxb., and *Dipterocarpus obtusifolius* Teijsm. ex Miq.

The result from the ground observation shows that the encroachment of agriculture, restaurant, and human activities on the riparian forest is increasing at the alarming rate. If these situations are not protected, the riparian forests will be depleted, leading to loss of water quality, habitats for plants and animal species, natural filtering of sediments and connectivity with other landscapes. The findings of ground investigation are a relation between image elements and vegetation cover, vegetation type, composition and setting, in which better understanding of riparian areas are reflected. The authors present the diversity of vegetation in the riparian zone of the lower Chi basin. The detailed information on the species listed should be further shown to make an appropriate management. Additionally, fast growing trees which affect the ecosystem functions are normally found in the terrestrial areas.

CONCLUSIONS

The result of the VCD showed that the BI, VI and SI over which the TI is applied to eliminate the shadow effects and the burning areas are introduced. The result of the VCD in the study area, the overall increase of the high VCD is apparently observed in 2015, as a result of introduction of fast growing trees and rubber trees while loss of native vegetation found. The results show that the riparian vegetation in the Lower Chi Basin, Northeast Thailand was classified in terms of the vegetation areas including aquatic, stream bank and terrestrial zones. The result of ground survey shows that 13, 18 and 14 the vegetation species are found in the aquatic areas, stream banks, and terrestrial zones, respectively. The encroaching cash crops, rubber trees and fast-growing trees on ecological native vegetation together with urbanization are remarkable trends. The result of GIS database shows that the distribution of vegetation adjacent to the river and its tributaries can be visually displayed. Additionally, in each of the VCD class the inventory of LCLU types and its changes was carried out and the vegetation mixtures in relation to its setting were found. For further study, the emphasis should be placed on the model makers, relationships between plant species, and its setting or geomorphology.

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REFERENCES

[1] Malanson, G.P., 1993, Riparian landscapes, Cambridge studies in ecology. New York (NY) Cambridge University Press, Cambridge, UK.

[2] Naiman, R.J., Decamps, H., and Pollock M., 1993, "The role of riparian corridors in maintaining regional biodiversity", Ecological Applications., 3, pp. 209-212.

[3] Nagaraja B., Sunil C., and Somashekar R.K., 2014, "Protection of riparian habitats to conserve keystone species with reference to *Terminalia arjuna* – A case study from South India", Biodiversity-The Dynamic Balance of the Planet, pp.95-109.

[4] Darveau M., Beauchesne P., Belanger L., Huot J., and LaRue P., 1995, "Riparian forest strips as habitat for breeding birds in boreal forest", Journal of Wildlife Management., 59, pp. 67-78.

[5] John L.S., Sponseller R., Dixon M., Gade K., Harms T., Heffernan J., jani A., Katz G., Soykan C., Watts J., and Welte J., 2005, "Riparian zones increase regional species richness by harboring different, not more species", Ecology., 86(1), pp. 56-62.

[6] Magdaleno F., and Martinez R., 2014, "Evaluating the Quality of Riparian Forest Vegetation: the Riparian Forest Evaluation (RFV) index", Forest Systems., 23(2), pp.259-272.

[7] Naiman R.J., Décamps H., and Pollock M., 1993, "The role of riparian corridors in maintaining regional biodiversity", Ecological Applications., 3(2), pp. 209-212.

[8] Bochenek Z., Ziolkowski D., Bartold M., Orlowska K., and Ochtyra A., 2018, "Monitoring forest biodiversity and the impact of climate on forest environment using high-resolution satellite images", European Journal of Remote Sensing., 51(1), pp. 166-181.

[9] Azizi Z., Najafi A., and Sohrabi H., 2008, "Forest canopy density estimating, using satellite images", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, pp. 1127–1130.

[10] Rikimura A., Roy P.S., and Miyatake S., 2002, "Tropical forest cover density mapping", Tropical Ecology, 43(1), pp. 39-47.

[11] Carneggie D.M., and Lauer D.T., 1966, "Uses of multiband remote sensing in forest and range inventory", Photogrammetria., 21(4), pp. 115-141.

[12] Hansen M.C., and Loveland T.R., 2012, "A review of large area monitoring of land cover change using Landsat data", Remote Sensing of Environment., 122, pp. 66-74.

[13] Hansen M.C., Defries R.S., Townshend J.R.G., and Sohlberg R., 2000, "GLC classification at 1 km spatial resolution using a classification tree approach", International Journal of Remote Sensing., 21(6-7), pp.1331-1364.

[14] Jun C., Jin C., Anping L., Xin C., Lijun C., Xuehong C., Chaoying H., Gang H., Shu P., Miao L., Weiwei Z., Xiaohua T., and Jon M., 2015, "Global land cover mapping at 30 m resolution: A POK-based operational approach", ISPRS Journal of Photogrammetry and Remote Sensing., 103, pp. 7-27.

[15] Lin C., Popescu S.C., Thomson G., Tsogt K., and Chang C.I., 2015, "Classification of tree species in overstorey canopy of subtropical forest using QuickBird images", PLoS ONE., 10(5), pp. 1-23.

[16] Pladsrichuay S., and Mongkolsawat C., 2016, "Integrated satellite-derived indices to estimate change detection of vegetation canopy density in the lower Chi Basin, Northeast Thailand", The 20th Computer Science and Engineering Conference., 20, pp. 47.

[17] Interior M.o., 1985, "Geological map of Thailand scale 1:250,000," Department of Mineral Resources.

[18] Baig M.H.A., Zhang L., Shuai T., and Tong Q., 2014, "Derivation of a tasseled cap transformation based on Landsat 8 at-satellite reflectance", Remote Sensing Letters., 5(5), pp. 423-431.