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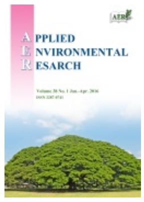

Assessing Vegetation Cover Change Using Remote Sensing: Case Study at Binh Duong Province, Vietnam

Nguyen Thi Huyen[1,*], Le Hoang Tu[2,*], Le Truong Ngoc Han[1], Vuong Thi Thuy[1], Dang Nguyen Dong Phuong[2], Nguyen Kim Loi[2]

[1] Faculty of Environment and Natural Resources, Nong Lam University - Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City 700000, Vietnam

[2] Research Center for Climate Change, Nong Lam University - Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City 700000, Vietnam

[*] Corresponding author: nt.huyen@hcmuaf.edu.vn and tu.lehoang@hcmuaf.edu.vn

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Abstract

This study aims to present the application of remote sensing in monitoring vegetation change in Binh Duong Province, Vietnam. The study used Landsat 5 images in the year 2010 and Landsat 8 images in the years 2015 and 2020 to investigate the area of vegetation. The maximum likelihood classification method (MLC) was used to classify land cover and an accuracy matrix was computed to validate the classification results. The references data were collected to support classification and accuracy assessment processes including land use maps in 2010, 2015, and 2020. In addition, collected field points and UAV (unmanned aerial vehicle) in 2020 were used. The overall accuracies are 81.27%, 84.41%, and 83.86%, and Kappa indices were 0.76, 0.80, and 0.80, corresponding to 2010, 2015, and 2020. The results showed that as compared to 2010 and 2015, the area of vegetation in 2020 decreased 10% and 8%, respectively. The average vegetation cover per capita was 740 m^2 $person^{-1}$ in 2020, compared to 1000 m^2 $person^{-1}$ in 2015 and 1200 m^2 $person^{-1}$ in 2010. This reduction was obvious in urban areas in the province, due to the need for construction and development. The study provides meaningful information on vegetation change and green area per capita in Binh Duong Province from 2010 to 2020.

Keywords: Binh Duong Province; Green space per capita; Remote sensing; UAV; Vegetation cover

Introduction

Vegetation is the base for all ecosystems [1–2]. Vegetation change detection provides valuable information for the local government to understand the relationship between natural and man-made environments [3–5]. Thus, it is important baseline information in resource management and planning activities [6–7]. The vegetation cover is a crucial index of environmental and social qualities, especially in urban areas. It supplies

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ecosystem services that benefit humans and the environment. In addition, urban green areas mitigate urban heat island effects which threaten human health [8]. Economic development, population growth, and overspread of urban and infrastructure systems have caused stress in harmonization between resource conservation and human demand [9]. Therefore, green area changes play vital information for local government in regards to making the plan of natural resource management [1, 9].

Because of the favorable natural condition such as fertile soil, warm and moist climate, Binh Duong Province Vietnam used to cover an extensive area of natural vegetation. However, large this area had been destroyed because of chemical defoliation in the Vietnam War [10]. In addition, the uncontrolled exploitation of natural resources for economic development added to the alarmingly decline of natural forests and vegetation areas [10–11]. Binh Duong Province was established in 1997 and in 2002 it completely changed from a province depending mainly on agriculture to an industrial one. Up to now, the economy in Binh Duong has developed significantly [11]. Nowadays, flora in Binh Duong is mainly from planted vegetation with rubber and other perennial orchards such as durian, mango, etc. [12].

The previous studies in Binh Duong Province reported that vegetation cover change has occurred recently due to the increase in urban areas [13] which causes negative impacts on ecosystems [14–17]. The study was conducted in Binh Duong Province by Thuy et al. showed that some vegetation species are at risk of disappearing due to the reduction of their natural habitat caused by urbanization [17]. Besides, loss of vegetation led to the negative impacts on groundwater and the local climate of cities that affect the quality of human life [18–19]. Binh Duong has been one of the centers of economic development in Vietnam. Binh Duong's strategy aimed to enhance the development of the economy as well as sustainable green area planning. Binh Duong issued Decision 183/QD-UBND on 17 November 2011 to harmony the economic development and natural resources conservation. This decision has enhanced the vital role of habitat for living-being such as the Sai Gon River corridor, natural and plantation forests which have been reduced due to the development of urban and infrastructure systems [20]. Hence, monitoring the vegetation changes in Binh Duong Province has been one of indices for supplying adequate information to the local government to make sustainable planning in natural resources conservation.

Remote sensing data is significant in obtaining and understanding the earth's surface [21–22]. It provides powerful data on Earth's surface observation at various spatial and temporal scales [23]. Land Use and Land Cover (LULC), as well as vegetation cover, play essential effects in ecosystem services, thus, it is one of the most frequent applications of satellite imagery [4, 15]. Optical imagery such as MODIS, Landsat, SPOT, and ASTER is often used in LULC research due to its wide coverage and longest history data [1, 23]. Many studies have used multi-temporal images and combined them with vegetation to enhance the ability of satellite images to identify vegetation areas [21, 24–26]. Vegetation indices are numbers generated using combinations of remote sensing bands that have relationships to the amount of vegetation to separate vegetation from non-vegetation such as water or bare soil [27]. There are commonly used vegetation indices such as NDVI (normalized difference vegetation index), LAI (leaf area index), and EVI (Enhanced Vegetation index). The most widespread index is NDVI which is used over the world for monitoring vegetation conditions and land cover changes [28]. NDVI splits up green plants from other surfaces based on the differential absorption of red wavelength by chlorophyll and reflection of NIR by green vegetation [21]. For high accuracy classification of satellite images and the establishment of land cover maps highly reliable, field data is important because it helps to understand the land cover types in the study area and builds the relationship between reality and satellite images, whether at the population or species level [1].

Given these considerations, therefore, it is necessary to quantitatively analyze the LULC change and its consequence to vegetation area using remote sensing technique. This study aims to evaluate the changes in the spatial distribution of green areas as well as average vegetation cover per capita in Binh Duong Province.

Materials and methods

1) Study area

The location of Binh Duong Province is in the Southeast of Vietnam (Figure 1). It occupies an area of 2,694 km^2. The terrain in Binh Duong is relatively flat, sloping from north to south because this province is the transition between the southern slope of Truong Son Mountain and Mekong Delta. Due to the suitable conditions such as monsoon tropical climate (average annual temperature around 26–27 ^{0}C and average rainfall about 1,800–2,000 mm) and fertile soil, Binh Duong had supported diverse and rich ecosystems which were composed of a great area of natural vegetation [10].

2) Data collection

To elucidate the vegetation change in Binh Duong Province from 2010 to 2020, the study used satellite images that were taken at three different times. In Vietnam, LULC has been assessed and updated every five years. It is the one of official map sources for satellite image accuracy assessment. The satellite imagery period of 2010, 2015, and 2020 has been selected as suitable with reference data. In addition, five years is enough long period to see obviously the changing in vegetation cover. These images have been acquired during the dry season (Table 1) to avoid cloud affecting.

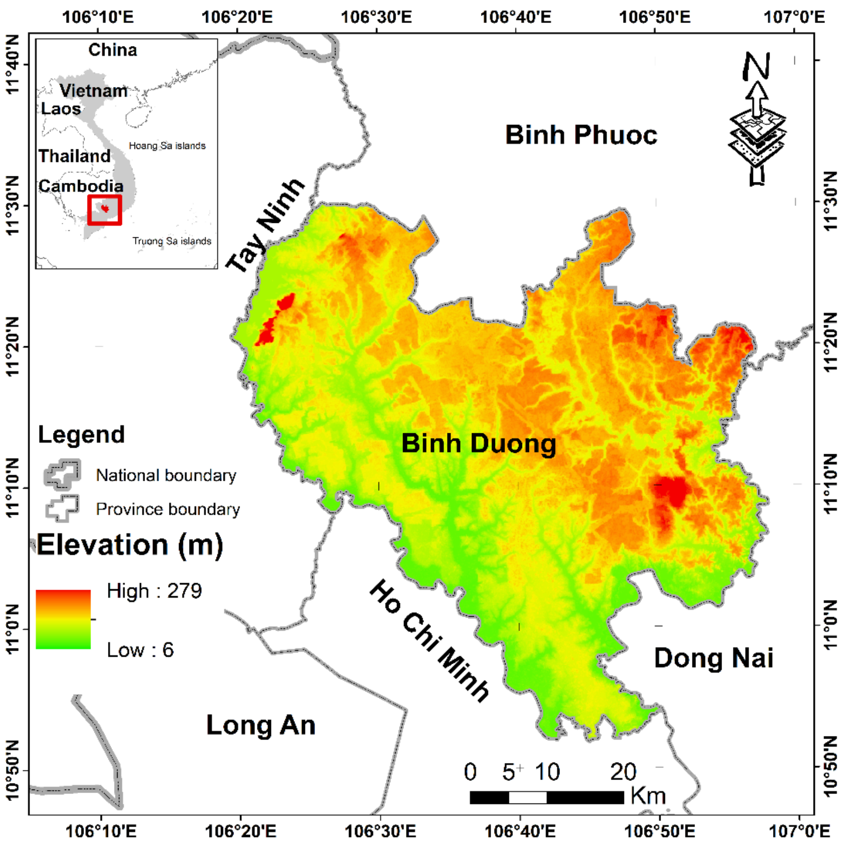


Figure 1 Research site location and elevation.

Table 1 Satellite images collection and selected bands in classification

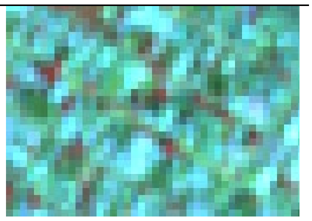
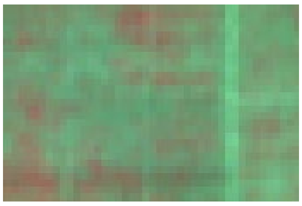
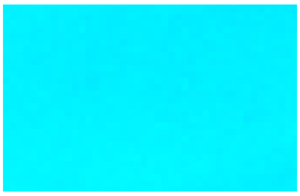
No.	Data	Date (dd/mm/yyyy)	Band	Wavelength (micrometers)	Spatial resolution (meter)	Source
1	Landsat TM	11/02/2010	Blue	0.450–0.520	30	https://earthexplorer.usgs.gov
			Green	0.520–0.600	30	
			Red	0.630–0.690	30	
			NIR	0.760–0.900	30	
			SWIR	1.550–1.750	30	
			NDVI			
2	Landsat OLI (8)	29/03/2015 23/02/2020	Blue	0.452–0.512	30	
			Green	0.533–0.590	30	
			Red	0.636–0.673	30	
			NIR	0.851–0.879	30	
			SWIR	1.566–1.651	30	
			Panchromatic	0.503–0.676	15	
			NDVI			

To support the classification and accuracy assessment, 153 field points were taken by stratified random sampling using GPS Map78 and seven spots were observed by UAV (unmanned aerial vehicle) Phantom 4. These data were also collected in the dry season of 2020 for minimizing the difference in surface reflectance between the dry and wet seasons. UAV method helped to collect data quickly and effectively. It showed the land cover of the study area with very high resolution that makes the researchers understand clearly about characteristics of each land covert type. In addition, the ground-trained data were collected on Google Earth with high-resolution satellite images. Besides, official land use maps in 2010, 2015, and 2020 were collected in the Department of Natural Resources and Environment of Binh Duong Province to support classification processing and classification accuracy assessment. The classification process used 70% of ground trained points as training samples. The last 30% has been used for accuracy assessment. The examples of land cover types collected in field trips were shown in Table 2. Besides, the statistics data on population and policies on social-economic plans were collected at the People's Committee of the province and districts. These data were used for assessing the change in vegetation cover per capita as well as for identifying the forces of this change.

3) Image processing and classification

Satellite image processing and classification were shown in Figure 2. After collecting data, all images were processed to minimize the effect of the atmosphere. Atmospheric correction is an important step in the case of imagery classification of multi-temporal or multi-sensor data [29–31]. This step aims to determine the real value of surface reflectance which is usually getting errors due to the atmospheric effects [32–33]. Dark-object subtraction was used in this study. It is one of the simple methods which has been used most widely for atmospheric correction [31, 34]. In each band, the darkest pixel values were found and subtracted from all pixels in the band. Then, NDVI was used to improve the identifying vegetation capacity. NDVI has been created and combined with selected bands of Landsat images (Table 1). This combination was proved that the classification could be improved, especially with vegetation areas [35].

Table 2 Land cover types in Binh Duong Province

No.	Land cover types	Photos from field trip	Field sampling points	Landsat 2020 (NIR_R_G)
1	Impervious area		34	
2	Bare land		22	
3	Water surface		18	
4	Dense vegetation		45	
5	Sparse vegetation		41	

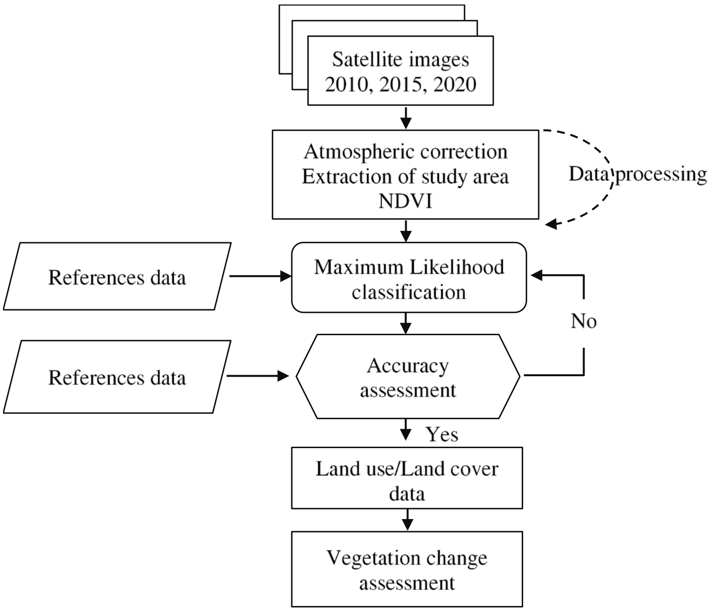


Figure 2 Research flowchart.

After data processing, Landsat images were classified. Various image classification methods and analysis techniques have been developed to facilitate satellite data interpretation and to extract as much information as possible from the images. Each method has its own advantages and disadvantages. In pixel-based techniques, the spectral properties of every pixel are analyzed without taking into account the spatial or contextual information related to the pixel. The maximum likelihood classifier (MLC) is one of the pixel-based techniques that has been used widely due to its high accuracy in image classification and suitability for medium spatial resolution satellite images such as Landsat [23, 36]. NDVI highlights the value of vegetation areas. Thus, combining NDVI and the other bands of Landsat image in MLC enhances the probability that a given pixel with vegetation cover has been classified correctly. Due to the focus on vegetation area, only five classes were classified including bare land, water surface, impervious area, dense (high coverage of vegetation), and sparse (low coverage of vegetation). In which, dense vegetation comprises natural forests, plantation trees with coverage over 60% [37]. Then, the accuracies of image classification results were assessed. Evaluation of classification results is an important process in satellite image classification. Accuracy assessment is a comparison of classification with ground-truth data to evaluate how well the classification represents the real feature. The error matrix and Kappa are the most common accuracy assessment approach [30]. The overall accuracy from the reference samples indicates what proportion was classified correctly. Meanwhile, the Kappa coefficient is the measure of how the classification results compare to values assigned by chance. Kappa analysis is recognized as a powerful method for analyzing a single error matrix and for comparing the differences between various error matrices [36]. In addition, the classification results were converted to shapefile and edited in ArcGIS to minimize the classification errors. Lastly, the vegetation change during the period of 2010–2020 was assessed.

Results

1) Classification and accuracy assessment

The classification results of Landsat images are shown in Figure 3. The classification results showed that Binh Duong Province was covered by a large area of vegetation. Agricultural land accounted for 77% of the total Binh Duong area in 2019 which was mostly distributed in Dau Tieng, Bau Bang, Phu Giao, and Bac Tan Uyen [38]. Most of this land is dominated by rubbers and orchards [12]. Meanwhile, industrial cities such as Di An and Thuan An comprised large impervious areas.

The overall accuracy was 81.27%, 84.41%, and 83.87% with the Kappa coefficient being 0.76, 0.80, and 0.80 in 2010, 2015, and 2020, respectively. The detailed accuracy assessment was presented in Table 3 for each category. Among the five classes, vegetation class (dense and sparse one) and water surface had higher accuracy (mostly >80%) than bare soil and construction class (mostly < 80%). Similar accuracy results have been reported in Dang and Mucsi study which also used a pixel-based method for land cover classification in the Binh Duong province [39]. The relatively high accuracies in land cover classification using medium satellite images such as Landsat and MLC method have also been demonstrated in previous studies [40–43].

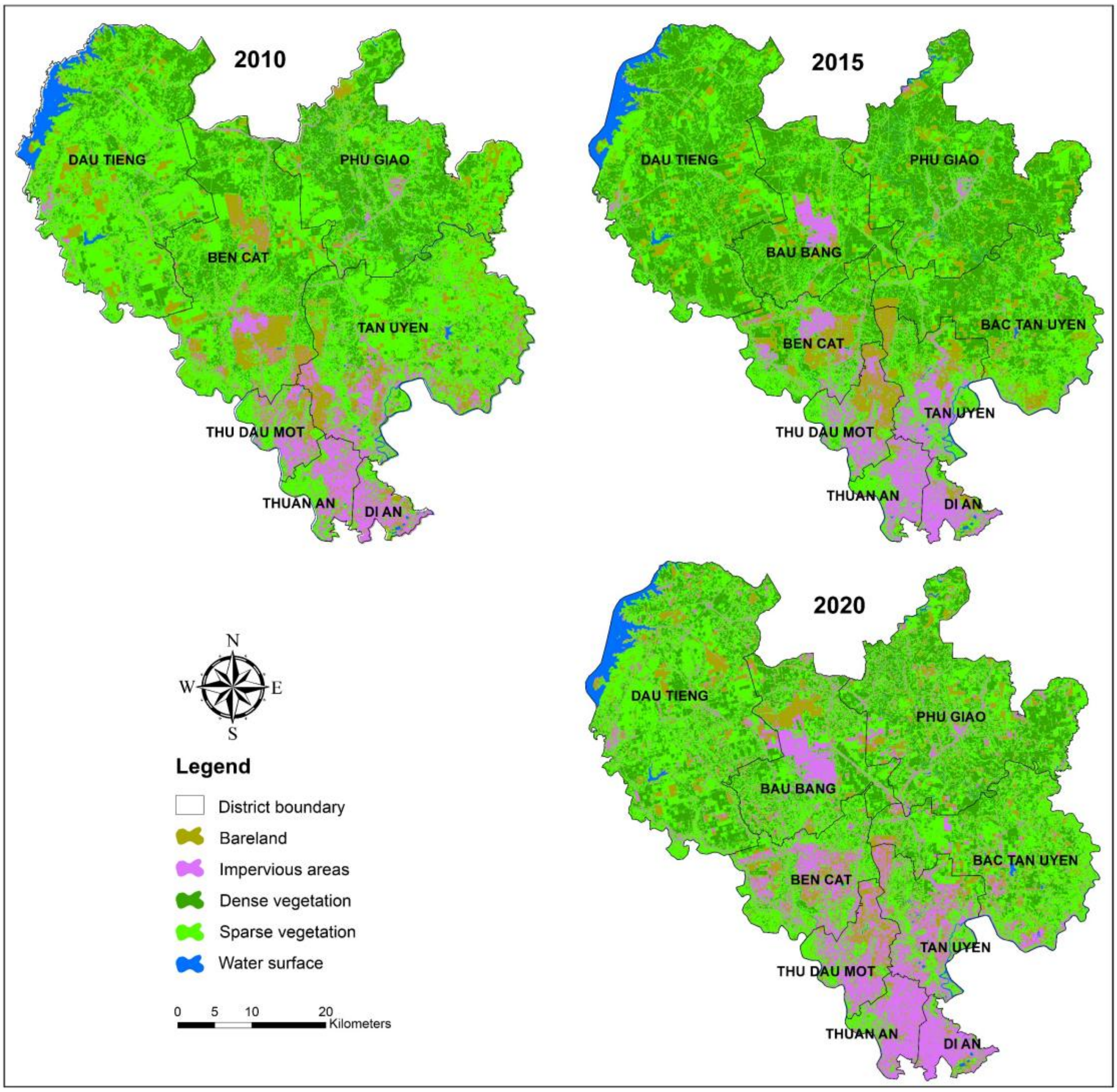


Figure 3 Land cover in Binh Duong Province in 2010, 2015 and 2020.

Table 3 Accuracy assessment

Year	Accuracy	Land cover type					Overall accuracy	Kappa
		Dense vegetation	Sparse vegetation	Water surface	Bare land	Impervious area		
2010	PA	92.35	84.17	91.03	56.29	73.89	81.27	0.76
	UA	91.88	88.98	87.12	61.15	68.21		
2015	PA	94.48	87.55	89.82	69.83	79.65	84.41	0.80
	UA	90.13	89.79	91.14	70.12	80.35		
2020	PA	91.86	82.97	86.47	77.35	77.31	83.86	0.80
	UA	87.29	86.97	98.66	83.15	60.29		

Remark: PA is Producer accuracy and UA is User accuracy.

2) Land cover change from 2010 to 2020

In the whole of Binh Duong Province, the bare land area was reduced by construction due to the urbanization and industrialization in this province. A large area of dense vegetation was converted to sparse vegetation while water surface area was slightly reduced from 2010 to 2020. In particular, the area of bare land decreased by 13.4% in 2015 and by 12.5% in 2020 as compared to 2010, respectively (Figure 4). The impervious surface increased obviously by 31.8% in the period 2010–2015 and by 42.3% in the period 2015–2020. The dense and sparse vegetation area fluctuated in this period. In 2010, there were 60,909.41 ha of dense vegetation and 140,803.47 ha of sparse vegetation. In the following 5 years, dense vegetation area increased sharply by 49% in the first period 2010–2015, then decreased by 34% in the second period 2015-2020. Conversely, sparse vegetation area decreased by 24.1% in 2015, then increased by 14.5% in 2020. Water surface area reduced year by year. It decreased by 2.8% in the period 2010–2015 and by 3.3% in the next period 2015–2020. In general, bare land and water surface decreased slightly while impervious areas increased significantly from 2010 to 2020. In terms of vegetation, both dense and sparse classes reduced to a slight extent from 2010 to 2020. In total, vegetation areas decreased slightly by 2.8% in the period 2010–2015 and 8.5% in the period 2015–2020. This land cover change trend has become the popular tendency in other places in Vietnam as well as in the whole country since the last two decades [42–44]. The increase of urban areas has been monitored around the world during the period. For example, Rimal et al. also reported this trend in the central east part of Nepal from 1988 to 2016 [45]. The increase of imperious and decrease of bare land and water may probably continue in the province in the future due to population growth and economic development pressures [46–48].

3) Vegetation covers per capita

The sum of dense and sparse vegetation area was calculated for each district belonging to Binh Duong province in 2010, 2015, and 2020 (Figure 5). Because Bac Tan Uyen and Bau Bang were established in 2013, they have not had data in 2010. The results presented in Figure 5 showed a decline in vegetation cover per capita in the period, from 1,245.2 m^2 $person^{-1}$ in 2010 to 1,014.56 m^2 $person^{-1}$ in 2015; and 741.57 m^2 $person^{-1}$ in 2020. A similar trend occurred in almost all districts of Binh Duong, except Phu Giao District. There was a decrease in 2015 as compared to 2010 (5,501.9 m^2 $person^{-1}$ in 2010 to 4,744.3 m^2 $person^{-1}$ in 2015) then the vegetation cover recovered and increased slightly in 2020 (4,845.21 m^2 $person^{-1}$). Although vegetation cover in Phu Giao decreased slightly from 2010 to 2020, the vegetation per capita increased around 100 m^2 $person^{-1}$ from 2015 to 2020. The decrease in the population of Phu Giao District in 2020 comparison to 2015 is the reason for this increase. The urban area which covers Di An and Thuan An City had the highest population in 2020 (480,502 and 603,539 people respecttively) and the lowest green patch (23.1 and 29.72 m^2 $person^{-1}$ correspondingly). Other remote districts having higher green cover are Dau Tieng, Phu Giao, and Bac Tan Uyen. These districts are covered by natural forests and plantations (e.g rubber) partially. The vegetation covers in Thuan An and Di An would be shrunk as these two districts are planned as the mega-urban zone with high population density [49]. Figure 6 showed an estimation of the green patch for each commune of the Di An City. It can be seen that Tan Binh had the largest green cover (175.6, 109.7, and 103.8 m^2 $person^{-1}$ in 2010, 2015, and 2020, respectively). On the other hand, An Binh was a ward that owns the smallest green cover (2.7, 1.8, and 2.5 m^2 $person^{-1}$ in 2010, 2015, and 2020, respectively). There were different trends in vegetation cover per capita in the communes in the Di An City during the period 2010-2020. For example, while vegetation covers per capita in Binh An commune increased from 65.7 to 74.2 and 80.8 m^2 person^{-1} in 2010, 2015 and 2020, vegetation cover per capita in Binh Thang commune decreased from 104.8 to 87.9 m^2 person^{-1} in 2010 and 2015 and increased to 96.4 m^2 person^{-1} in 2020. Although vegetation cover in Binh Thang commune increased slightly from 2010 to 2020, the vegetation per capita decreased by around 16.9 m^2 person^{-1} from 2010 to 2015. The reason might because the increase in the population of the commune during the period 2010-2015.

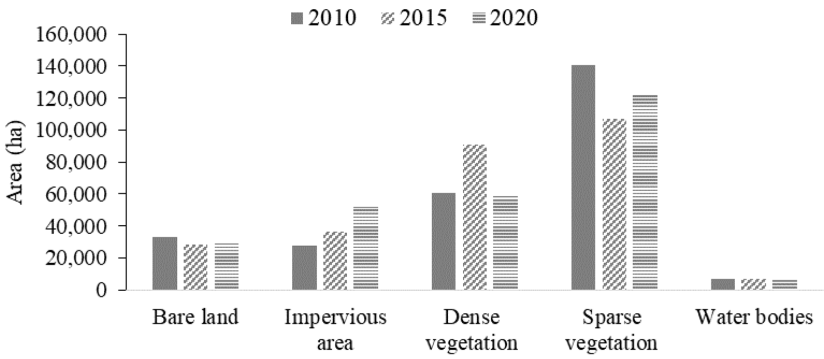


Figure 4 Change in LULC classifications in Binh Duong Province in 2010, 2015 and 2020.

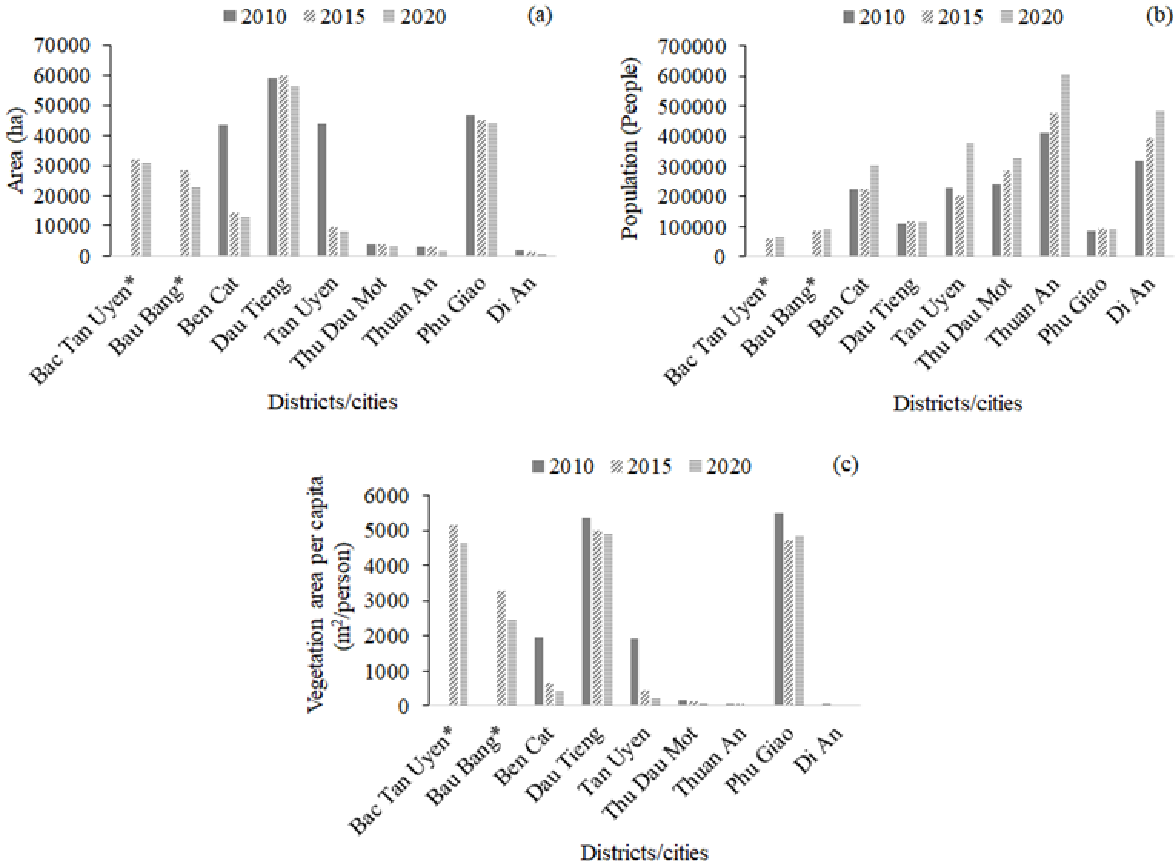


Figure 5 Vegetation area per capita in district category from 2010 to 2020 (m^2 person^{-1}) including (a) vegetation cover, (b) population, (c) vegetation area/person.
*Resolution 136/NQ-CP issued on December 29, 2013, on splitting Ben Cat District into Ben Cat and Bau Bang and splitting Tan Uyen into Tan Uyen and Bac Tan Uyen.

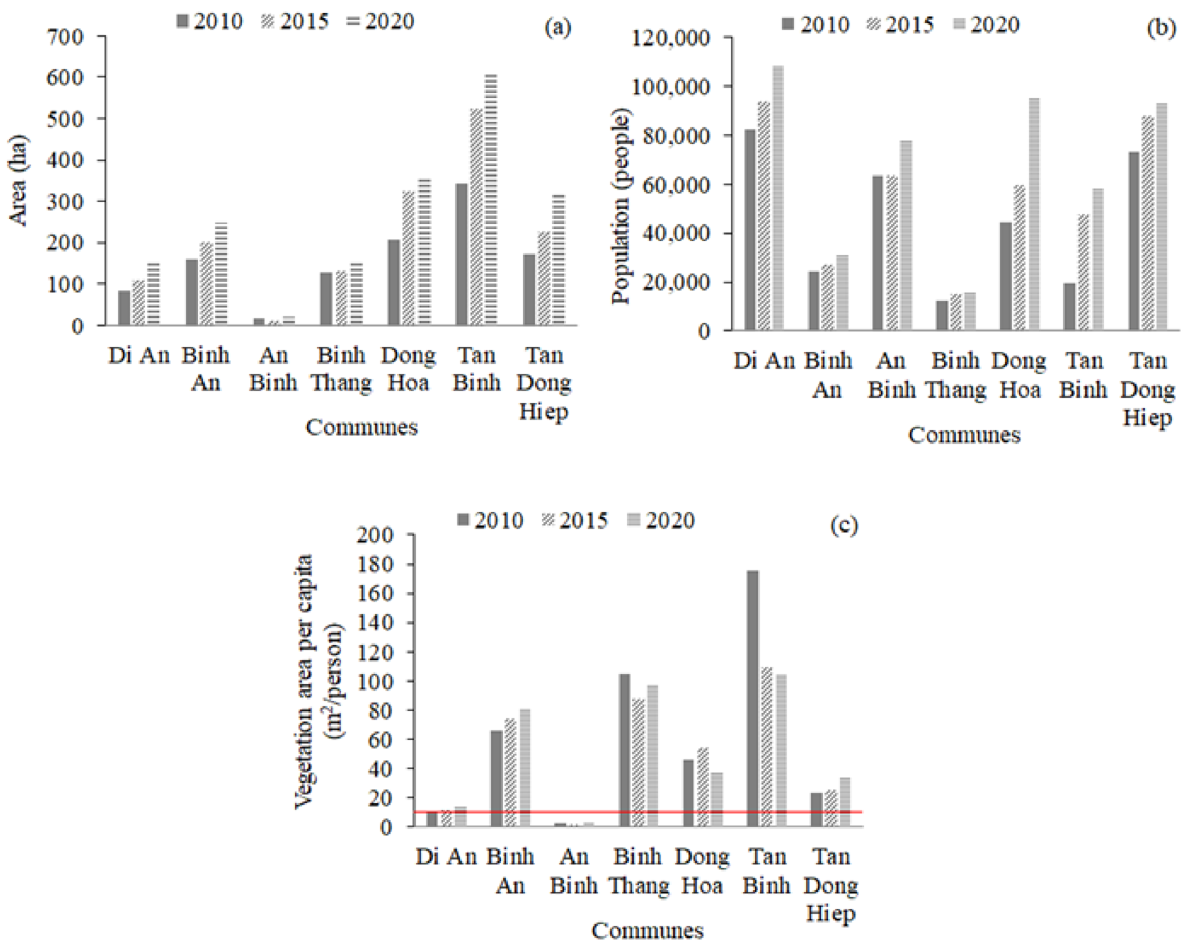


Figure 6 Vegetation area per capita in Di An city from 2010 to 2020 (m^2 person^{-1} including (a) vegetation cover, (b) population, (c) vegetation area/person. The line in 6c is the Vietnamese national standard on greenery planning for public utilities in class-3 urban.

Discussion

In Vietnam, the national standard for vegetation cover per capita has not yet been established. The national standard TCVN 9257:2012 on greenery planning for public utilities in urban areas indicates that urban at classes 1 and 2 must have the public vegetation per capita from 10–12 m^2 while urban at classes 3 and 4 are from 9–11 m^2 [50]. The public vegetation in this standard only includes plantations in parks and along the roads. Thu Dau Mot is categorized as the class 1 urban city while the Di An, Thuan An, Ben Cat, and Tan Uyen are categorized as cities at class 3 urban. Di An City is one of the centers of trade, economic, social, transportation in Binh Duong. This city accounts for only 2.23% area of the whole province but it is home to 19.6% of inhabitants of Binh Duong in 2020. In the specific case of the Di An City (Figure 6), vegetation cover per capita in the An Binh commune was about 3 to 4 times lower than the national standard for green spaces per capita in the class-3 urban (9–11 m^2 person^{-1}). This is also 3.6 times lower than the World Health Organization (WHO) standard which set a minimum limit for urban green spaces per capita of 9 m^2 [51]. With the speed of economic growth in this city, the demand for construction would increase. If the trend is maintained, some of the other communes would not meet the national standard for green spaces per capita, for instance, Di An Ward.

In Vietnam, the shortage of urban green spaces has been mentioned in Ha Noi, Ho Chi Minh

City (HCMC), and Nha Trang in previous studies. Particularly, Khuong Van and Tran Huong concluded that the green space in Ha Noi was different between center and suburb. The suburb areas such as Long Bien had the green space per capita higher than the national standard of TCVN 9257:2012 with 134.2 m^2 $person^{-1}$ in 2016. Meanwhile, the center such as Dong Da had a very low green area per capita with only 2.5 m^2 $person^{-1}$ in 2016 [52]. Another study was conducted in HCMC showed similar results. The inner-city area had a very low green space index with approximately 3 m^2 $person^{-1}$ in 2017. The other six new districts such as District 7, 12, 2, 9, Binh Tan, and Thu Duc had a high green space index (higher than 28.5 m^2 $person^{-1}$) [53]. Similarly, Van et al. used Landsat and ALOS to determine green space by the MLC method. The results showed that the green space area in Nha Trang city was even severe shortage than that in HCMC and Ha Noi. In some areas such as Van Thanh, Phuoc Tien Ward, the green space was less than 1 m^2 $person^{-1}$ in 2017 while other inner-city areas had green space less than 10 m^2 $person^{-1}$. This index was higher in suburbs with over 100 m^2 $person^{-1}$ [54]. These studies demonstrated that optical images such as Landsat and the MLC method have been successful in monitoring urban green space. The results of these studies also showed that the green space in some urban was shortage compared with the national standard. The failure to meet green standards in landscape planning was alarming. In addition, NDVI has been used to enhance the green space. The previous studies shows that each vegetation index has its own advantages and it may be suitable for specific cases. For example, Qui et al. in their study stated that in density vegetation estimation, EVI can get a better result than NDVI [55] while Li et al. concluded that in their research NDVI had a better correlation with field data of vegetation cover than EVI [56]. Hence, consideration of choosing vegetation index may be studied in future research. In the world, over recent decades, the number of studies in urban green spaces has rapidly increased. Most studies have been conducted to map and classify urban green spaces which cover large areas [57]. To be specific, Shahfahad et al. stated that green spaces in 50 of 64 wards in Delhi, India were under 9 m^2 $person^{-1}$ [51]. Another study in Iran also concluded that the urban green space in Khorramabad was 6.88 m^2 $person^{-1}$ [58]. Thus, the urban green spaces in these cities did not meet the universal standards.

The main reason for vegetation change in Binh Duong Province is urban expansion. According to Decision No. 1701/QD-UBND issued on June 26, 2012, Binh Duong Province pursued the target of urbanization up to 85% in 2020. In the next period 2020-2030, there will be more industrial zones and transportation systems. With this regard, the vegetation cover will be decreased. However, the local authority claims to maintain 65% of vegetation cover in the period 2020–2030 [59]. In addition, following economic development and urbanization, the population in Binh Duong increased year by year due to the labor demand in industrial zones. Thus, the ratio of vegetation per capita in industrial areas such as Di An and Thuan An City reduces from 2010 to 2020. Urbanization has been the important factor causing the decrease of green spaces in cities which was mentioned in the previous studies in Vietnam and over the world [52, 57, 60–61]. As the consequence, the loss of green space causes negative impacts on the ecosystem and the quality of human life. Recent studies in Binh Duong Province have proved that vegetation cover decreased makes groundwater and habitat for species decline [17, 19]. Urbanization and green cover loss make urban heat islands increase that affecting human health [18].

The economic and social development in Binh Duong Province has been obtained by expanding the urban and industrial zones. As the result, the vegetation cover is reducing year by year. It is hard to judge the green area per capita at the moment because the national standard is for the green area only in parks and roads. It is necessary to develop standards for a typical type of green area such as parks, corridors, natural forests, and planted forests due to their distinguished environmental function. Another concern is green patches distribution and size. As the continuous and large green areas are much better than the disconnected and sparse ones in terms of ecology but this research, they were considered in the same weight. In the upcoming study, the green area of parks and roads should be separated to assess rightfully according to the national standard. In addition, the size and structure of the green area should be focused on.

Conclusion

The practical use of the geospatial approach involving GIS, remote sensing, and census data stands appropriate for determining vegetation change and green area per capita in Binh Duong Province from 2010 to 2020. By combining UAV spots and field sampling points, the study has classified successful land covers in Binh Duong Province with satisfactory overall accuracy and Kappa coefficients for 2010, 2015, and 2020, respectively. Binh Duong Province has still covered by large green areas, especially in the agricultural districts such as Dau Tieng, Phu Giao, Bac Tan Uyen, and Bau Bang. However, the green spaces tend to decrease slightly and be replaced by impervious areas. The urban in the province has a reduction of vegetation for every period. With the high speed of urbanization in these cities, the green space might reduce fast. Resulted, the green areas per capita will be deficient. It may cause negative impacts on human health, landscape, and ecological services. This research is the first study to determine the change in green area per capita from 2010 to 2020 for the whole Binh Duong Province using the geospatial approach, including GIS, satellite imagery, and UAV. Therefore, the study has practical significance in providing readers with specific data on the change of vegetation, and the green area per capita in each district, especially in Di An City through three periods 2010, 2015, and 2020. Green space per capita is one of the criteria to evaluate the quality of human life and environmental quality. Hence, this information is valuable for the stakeholders such as local people, local governments, and investors. The land-use planners and policymakers can make decisions towards harmonizing economic development and sustainable green place based on the findings of this study. The methodology adopted in this study can be utilized effectively in other areas to evaluate the green spaces for enhancing environmental quality and the quality of human life. Besides, the upcoming research should consider using the various vegetation index to improve the accuracy of satellite image classification.

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