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Assessing the conversion between agricultural and built-up area in the Vu Gia - Thu Bon river basin

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Abstract:

The conversion of agricultural land into developed infrastructure entails trade-offs. Therefore, studying the dynamics of change between agriculture and developed areas is essential. This study utilizes remote sensing technology to study this dynamic. In particular, satellite images were utilized to assess the current land use master plan for the period of 2011-2020 in the Vu Gia - Thu Bon river basin, Vietnam. Land cover before and after implementation of the land use master plan was classified using three indices of the Normalized Difference Water Index (NDWI), the Normalized Difference Vegetation Index (NDVI), and the Normalized Difference Built-up Index (NDBI). Two main land cover types of paddy rice cultivation area and developed area were compared for the two time periods. The land cover classification results revealed that the land use master plan in the river basin has achieved its conversion target four years ahead of schedule. Additionally, the changes were thoroughly assessed within the context of socioeconomic development in the river basin. Land cover changes in the river basin created five major implications for policymakers, including the need to reassess the land use master plan target, the need for regulatory measures in housing development, the true nature of the paddy rice conversion mechanism, the irreversible nature of agriculture land conversion, and market conditions for newer agricultural products.

Keywords: **agriculture, change detection, land cover, land use.**

Classification number: **5.1**

Introduction

Vietnam is currently undergoing radical economic transformation [1]. The economy, once heavily dependent on agricultural production, is now geared towards "industrialization and modernization" [1, 2]. As a result, an increasing amount of agricultural land is being converted into non-agricultural uses throughout the country [3-5].

Land use change, however, creates trade-offs that must be viewed cautiously at the policy level. Farmland and forest land converted to urban development provide better living standards and fuel economic growth in the urban area, however, the conversion creates problems related to the environment and society [3, 4, 6, 7-10]. Reduction in areas for food and timber production could reduce the livelihoods of those dependent on the sector while soil erosion, salinization, desertification, and soil degradation reduce soil quality [11].

Urbanization further presents many socioeconomic challenges in the form of conflicts between agricultural and non-agricultural land uses [12]. For example, local farmers may be forced to compensate for the negative impacts generated by agriculture on nearby residents. Furthermore, when the total amount of farmland falls below a certain threshold, the local agricultural economy may collapse as all agricultural-supporting sectors disappear [13]. Conflicts directly related to land appropriation and reallocation are also a hotly debated issue [3, 4].

Given the importance and relevance of agricultural land use conversion in Vietnam, there has been a great deal of research on the topic. The rich body of research in different areas suggested that land use in Vietnam has been highly dynamic and has changed significantly in the past. Additionally, there is a general consensus that these changes have major social, environmental, and economic implications. Binh, et al. (2005) [14], Hauser, et al. (2017) [7], and Hanh, Thuc, Kervyn (2015) [8] studied the land

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cover conversion within Ca Mau province in Southern Vietnam using remote sensing and concluded that the increase in built-up area has been significant at the cost of agricultural land. Disperati and Virdis (2015) [6] and Phuc, Van Westen, Zoomers (2014) [3] studied the land cover change dynamic in Thua Thien - Hue province in Central Vietnam and found that urban areas have encroached on peri-urban agriculture areas. While Disperati and Virdis (2015) attributed the changes to population increase and policies, Phuc, Van Westen, and Zoomers (2014) argued for a case of change due to policies and market forces. A more holistic research for entire Vietnam was conducted by To, Mahanty and Dressler (2015) [12] and Saksena, et al. (2014) [15]. These studies concurred that reduction in agricultural land is observed with an increase in built-up area.

This research provided a case study for the Vu Gia - Thu Bon river basin (VGTB) in Vietnam. The effectiveness of the ongoing land use master plan for the period of 2011-2020 is thoroughly studied using remote sensing technologies. The major objectives of the study include: 1) Identify and map the land cover in the VGTB river basin before and after the current land use plan; 2) Detect the changes of land cover between agricultural and non-agricultural land in the river basin; 3) Determine the total effectiveness of the plan in terms of the agricultural and the built-up area components; and 4) Critically review the changes as a result of the land use master plan and their implications for policies in the future. The study not only thoroughly assesses the effect of land use planning in the river basin but also provides information so that future policies could be better designed for sustainable development.

Materials and methodology

Study area

VGTB river basin is located in the Central coastal zone of Vietnam (Fig. 1). The total catchment area of VGTB is approximately 10,350 km^2 and covers Da Nang city and Quang Nam province. The total population in the river basin is approximately 2 million (2018 census).

Agricultural production remains one of the most important economic sectors in the river basin, with the agricultural sector employing roughly half of the population [16]. Paddy rice remains the dominant crop with approximately 70% of the irrigated agriculture area devoted to rice. Within the last several years, the river basin has seen rapid development. A large proportion of existing agricultural land has been converted into non-agricultural land as a result of both national and local policies.

National policies include the 7th Resolution in 1994 and the 15th Resolution in 2002 of the Vietnam Communist Party (the ruling party in Vietnam) [17, 18]. While the 7th Resolution promotes industrialization and modernization

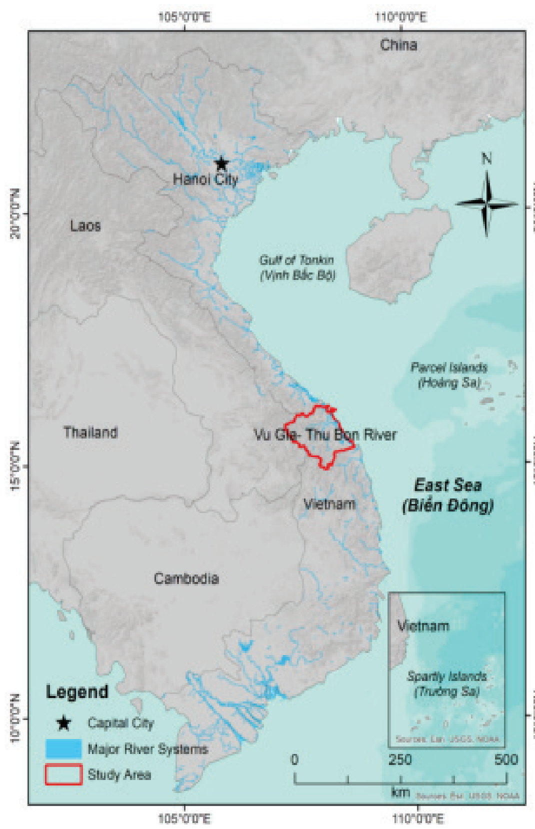

Fig. 1. Location of the study area.

of the economic sector for the time period of 1994-2000, the 15th Resolution promotes the same process for the time period of 2001-2010. Later policies also hinted on the same direction for economic development for later time periods.

Local policies in the VGTB river basin therefore must fall into national policy lines and are aimed towards building a stronger industrial sector and reducing reliance on agriculture. One important piece of policy in the river basin includes the land use master plan for both Quang Nam and Da Nang for the time period of 2011-2020 [19, 20]. Agricultural area is expected to decrease while built-up area increases.

Data

Satellite images covering the entirety of the VGTB river basin are utilized for the study. A high-resolution SPOT image from AIRBUS and the widely used Landsat image from the United States Geological Survey are used. A SPOT 7 image was acquired for the area within Da Nang city while Landsat images include both the Landsat 5 and the more recent Landsat 8 data. A total of 10 Landsat scenes were used in the study, including five Landsat 8 scenes and five Landsat 5 scenes. Images for 2016 and 2017 were provided by Landsat 8 while images for 2010 and 2011 were provided by Landsat 5. The Landsat 5 data were used in place of the

Landsat 7 data due to a Landsat 7 mission sensor error (scan line error).

The Landsat scenes used in the study are listed in Table 1. The selection of the scenes is due to the level of cloud coverage and for multi-temporal NDVI assessment.

Table 1. LANDSAT satellite images used for the study.

Data	Date	Scene names
Landsat 8 OLI (30x30 m)	8th March 2016	LC81240492016068LGN00
	8th March 2016	LC81240502016068LGN00
	25th April 2016	LC81240492016116LGN00
	2nd May 2016	LC81250492016123LGN00
	11th March 2017	LC81240492017070LGN00
Landsat 5 TM (30x30 m)	7th February 2011	LT51240492011038BKT00
	7th February 2011	LT51240502011038BKT00
	5th July 2010	LT51250492010186BKT01
	11th May 2010	LT51240492010131BKT01
	12th June 2010	LT51240492010163BKT01

The land use master plan for Quang Nam province and Da Nang city for the period of 2011-2020 [19, 20] were further utilized. Two main land cover types are the focus, including the changes in agricultural area and the changes in built-up area. Changes in the agricultural and built-up areas are summarized in Table 2. Informal development is not considered within the scope of this study.

Table 2. Land use type changes in Quang Nam and Da Nang until 2020.

Land use type	Quang Nam (km^2)	Da Nang (km^2)	Total change (km^2)
Agriculture (rice)	- 33.12	- 13.48	- 44.6
Built-up	+ 242.03	+ 50.54	+ 292.57

Methodology

The effect of land use plans in the river basin is determined through a land cover change detection procedure. This includes classifying land cover based on Landsat images in two time periods prior to and after the land use master plan and comparing the classification. The changes could thus be analyzed.

Land cover classification:

This study classifies land cover largely based on the six cover types in the Intergovernmental Panel on Climate Change's (IPCC) recommendation [21]: grassland, agriculture, forest, water, built-up area, and others. However, this study utilized only five types of land cover, namely, water, vegetation, agriculture, empty land, and built-up area.

Grassland cover in the definition of IPCC does not exist in the study area. This includes the non-existence of rangelands and pasture lands. For this reason, the vegetation class used in the study is a combined class of forest, bushes, and other types of vegetation that do not fall into the category of agricultural land. It is true that combining the two land covers creates higher inaccuracy in general, however, the purpose of the study is the focus on assessing changes in agricultural area and built-up area. Therefore, this land cover type of vegetation does not impact the overall accuracy of the assessment.

A further assumption is made during the classification of agricultural area in the river basin. In particular, given that the majority of the agricultural area in the river basin is paddy rice, agricultural land cover would thus be assumed to be paddy rice. A detailed description of the various land cover classification is illustrated in Table 3.

Table 3. Description of land cover class classification.

Land use type	Description
Water (Wa)	Wetland class from IPCC's classification and includes permanent open water, lakes, reservoirs, and streams
Vegetation (Ve)	Lumping of forest and grassland from IPCC's classification. The land cover includes: production forest, natural forest, special use forest, protected forest, grassland, perennial crops, annual crops
Agriculture (Ag)	Paddy rice
Empty land (Em)	Similar to other land class from IPCC. Includes bare soil, and sandy beaches
Built-up (Bu)	Similar to settlement class from IPCC. This includes: residential, commercial, industrial, and other urban land

Land cover classification is based on indices, namely the NDVI, NDWI, and NDBI. ERDAS Imagine software package was used for the purpose of land cover classification.

The land cover classification procedure is based on thresholding of the indices. A three-level classification scheme is applied where thresholding indices provide the first level of classification of vegetation and agriculture, water, empty land, and built-up area. A second level of classification involves performing multi-temporal NDVI through the use of a number of Landsat images. This procedure separates vegetation and agriculture land cover classes. Thresholding was also performed to separate empty land and built-up area in the NDBI. A classification decision tree is illustrated in Fig. 2.

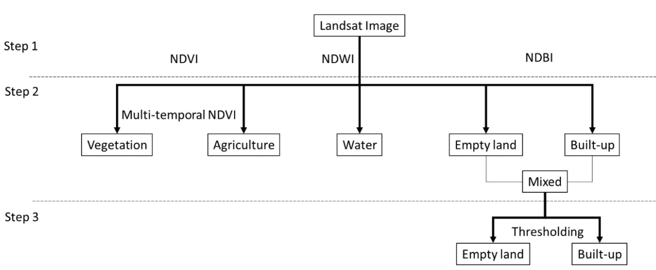

Fig. 2. Hierarchy classification scheme for land cover mapping.

Accuracy assessment:

An overall accuracy index and the Kappa coefficient are used to determine the accuracy of the classification scheme. Reference points for accuracy assessment are selected from Landsat images with the aid of high-resolution Google Earth images. This method has been attempted by other studies [22-24]. Both random points and points that could potentially be misclassified were selected. The minimum number of reference points followed the rule established by McCoy (2005) [25], where:

$$N = Z^2(p)(100-p)/E^2 \quad (1)$$

with N being the number of sample points, $Z = 2$ (standard normal deviate for a 95% confidence interval), p is expected accuracy, and E is allowable error (100- confidence interval). For this study, an accuracy of 85% is expected, therefore, a minimum of 204 samples would be required.

Additional ground truthing points were obtained to reassess and validate the choice of ground reference points selected for the classification scheme in 2016. This was carried out in early 2017. The reassessment of ground reference points in 2011 could not be carried out through ground truthing and, since there are no other available data, was not accomplished. The location of ground reference points for the classification of land cover is illustrated in Fig. 3.

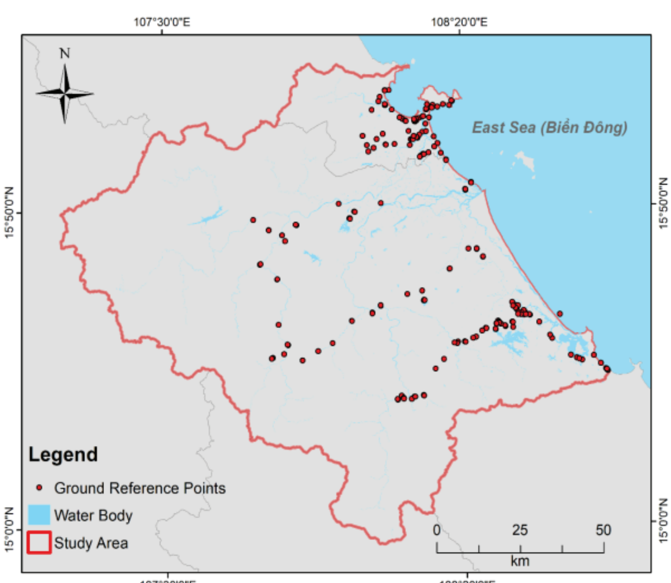

Fig. 3. Ground reference points for accuracy assessment.

The land cover classification results from the study are further compared with land use statistics. More specifically, the total land area of the different classes was compared with the land use inventories from the Vietnam Ministry of Natural Resources and Environment (MONRE) in 2010 and 2015. Through comparison of the land cover classification with the land use inventory data, the relative accuracy of the land cover classification scheme could be established, providing an additional level of assessment. It should be noted, however, that there is a mismatch of timescale between the land cover classification and the land use inventory. In particular, land cover classification was performed for 2011 and 2016 while the land use inventory was available for 2010 and 2015. Additionally, there also exists a slight difference between land cover and land use. Therefore, small discrepancies between the two could be found.

Results and discussions

Land cover classification results

Land cover classification for the years 2011 and 2016 are illustrated in Fig. 4. The corresponding accuracy assessments are listed in Table 4.

Table 4. Accuracy assessment of land cover classification using indices.

Accuracy measurement	2011	2016
Overall accuracy (%)	82	85
Kappa coefficient	0.77	0.81

Land cover classification for both 2011 and 2016 using indices is relatively successful. For land cover in 2016, the overall accuracy and Kappa coefficient are 85% and 0.81, respectively. Likewise, the overall accuracy and Kappa coefficient for the land cover classification scheme in 2011 are 82% and 0.77, respectively. The level of accuracy and Kappa coefficient are deemed sufficient compared to other studies [8, 26, 27], therefore, the results are accepted for further analysis.

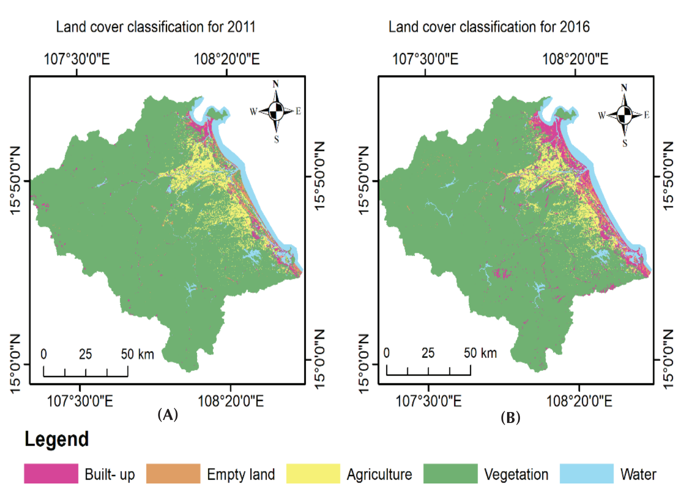

Fig. 4. Classification of land cover in VGTB river basin.

Table 5. Producer's and user's accuracy of land cover classification.

Class	2011		2016	
	Producer's	*User's*	*Producer's*	*User's*
Water (Wa)	74.5	100.0	86.3	100.0
Vegetation (Ve)	91.0	76.3	80.6	84.4
Agriculture (Ag)	86.8	100.0	91.4	97.0
Empty land (Em)	83.3	62.5	78.6	84.6
Built-up (Bu)	71.1	72.7	87.7	71.4

The user's and producer's accuracy for the classification are listed in Table 5. Producer's accuracy represents how well reference points are classified. On the other hand, user's accuracy represents the probability that a pixel classified into a given category actually represents that category on the ground.

The classification scheme in 2016 is more successful than the classification scheme in 2011 given the producer's and user's accuracy levels. For the classification scheme in 2011, a low producer's accuracy for water and built-up classes indicated that the classification of these pixels does not agree well with the ground reference points. For the classification scheme in 2016, a low user's accuracy level indicates a misclassification of built-up with other types of land cover.

A general case in the classified image is the domination of vegetation cover. This is mainly due to the vegetation growth even in sandy areas within the river basin (Fig. 5). As such, the reflectance of the satellite image reveals a highly green area (also mostly due to the coarse resolution) and the NDVI measure indicates these areas are covered by vegetation. This classification as a whole is not false.

Fig. 5. Example of empty land covered with vegetation.

The comparison of total land cover for the different classes was also compared with the land use inventory issued by the MONRE (Table 6). It should be noted that the area of only four out of the five land cover classes was compared. The total area of surface water is not compared given the limited information within the land use inventory.

From the comparison, land cover classification results and the land use inventory agree well with each other in the order of magnitude. However, notable differences are worth discussing. Without losing much accuracy and for the purpose of the discussion, an under-prediction of the land cover classification indicates that, for a particular land cover class, the area in the land cover classification scheme is smaller than the area in the land use inventory. Likewise, an over-prediction of the land cover classification implies that the area of a particular land cover in the classification scheme is greater than the area of the same land cover in the land use inventory.

Table 6. Comparing land cover results with land use data from MONRE (units: km^2).

		Vegetation	Agriculture	Empty land	Built-up
2011	Classification results	10,344.09	635.26	180.91	200.58
	Land use (MONRE)	10,316.29	607.84	156.05	280.60
	Difference	27.80	27.42	24.87	-80.03
	Difference (%)	0.27	4.32	13.74	39.90
2016	Classification results	10,036.95	581.39	181.92	543.03
	Land use (MONRE)	9,983.24	566.63	169.61	623.94
	Difference	53.71	14.76	12.31	-80.91
	Difference (%)	0.54	2.54	6.77	14.90

For 2011, there is a significant magnitude of mismatch of built-up area between the land cover classification scheme and the land use inventory. In particular, the land cover classification scheme provided approximately 80 km^2 less built-up area than the land use inventory data. Given that the total land area of all four classes must be the same in both the land cover classification and land use inventory, the under-prediction of built-up area is compensated for by the over-prediction of vegetation, agriculture, and empty land.

A similar over-prediction and under-prediction pattern is observed between the land cover classification scheme and the land use inventory in 2016. In other words, the land cover classification scheme consistently under-predicts the total area of built-up land while it over-predicts the total area of vegetation, agriculture, and empty land.

The lower-than-expected accuracy of the land cover classification when compared to the land use inventory is mostly attributed to the coarse resolution of the Landsat images. This is illustrated in Fig. 6. A Landsat 8 image of the Central Business district (CBD) of Da Nang city along the banks of the Han river is displayed side by side with a SPOT 7 image. Using the same two satellite scenes, the classification of the built-up area is also shown. The selected area has been highly developed. Therefore, there is little change between 2015 (the date of the SPOT 7-acquired data) and 2016 (the date of the Landsat 8-acquired data). Therefore, comparison of the two is meaningful.

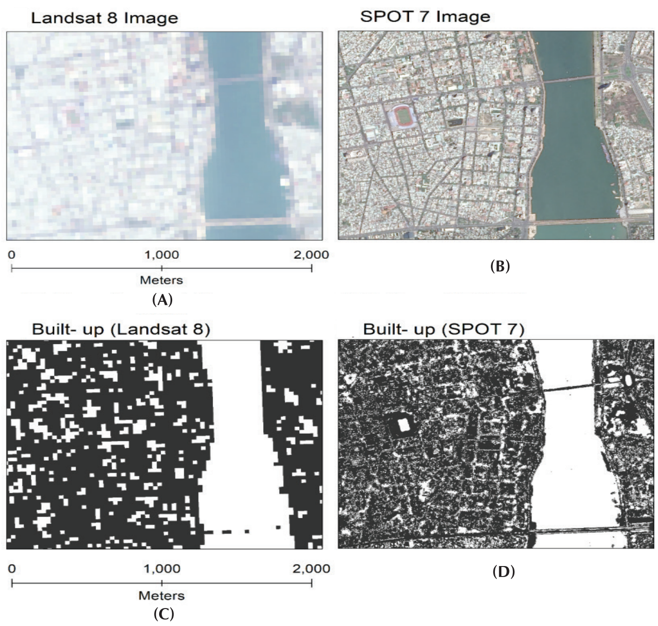

Fig. 6. Comparison of Landsat 8 and SPOT 7 images.

The SPOT image has a higher base resolution (1.5 mx1.5 m) when compared to the Landsat 8 image (30 mx30 m). Given the higher resolution, the SPOT image provided a better classification result of the built-up area within the CBD of Da Nang city within the river basin. This is also true when using the SPOT image to classify other land cover classes as compared to the Landsat image. The coarse resolution of the Landsat 8 image thus creates a major source of uncertainty and error in the classification of land cover in the study. An overall low accuracy of the classification scheme is therefore explained.

Land cover change detection

Land cover change detection was performed and a change matrix is illustrated in Table 7. The rows demonstrate the magnitude of changes that a particular type of land cover in 2011 underwent. The columns display the total area into which a particular land cover in 2011 was converted. For example, 580.13 km^2 of water in 2011 remained as water body in 2016. However, 2.32 km^2 of water in 2011 was converted into vegetation by 2016.

Table 7. Land cover change matrix between 2011 and 2016 (units: km^2).

		2016					
		Wa	*Ve*	*Ag*	*Em*	*Bu*	*Change*
	Water (Wa)	580.13	2.32	0.45	4.05	23.42	17.53
	Vegetation (Ve)	35.45	9,936.38	14.12	52.42	305.72	-307.13
2011	Agriculture (Ag)	1.91	53.81	566.37	3.06	10.11	-53.86
	Empty land (Em)	4.79	14.51	0.45	105.73	55.42	1.01
	Built-up (Bu)	5.63	29.93	0.00	16.65	148.36	342.45

The conversion of agriculture and vegetation is highly interesting. Approximately 53.81 km^2 agricultural land was converted into vegetation between 2011 and 2016. In the other direction, 14.12 km^2 of vegetation in 2011 was converted into agriculture by 2016. This could suggest an error in the classification scheme where a small amount of paddy rice area was not fully detected in the multi-temporal NDVI analysis. The error in classification leads to an agricultural area being falsely classified as vegetation in 2011.

Conversion of built-up area into other types of land cover should be viewed cautiously. This is mainly due to the fact that this conversion mechanism is not normally expected. Once an area has undergone development and is converted to built-up infrastructure, very rarely is this area converted back into vegetation, agriculture, or empty land.

The conversion of built-up area into water in the classification scheme could be attributed to several reasons. This includes the excavation of new artificial lakes in the city of Da Nang, the seasonal fluctuation of water in streams (flooding), and errors in classification. Water surface has a similar reflectance with built-up area when using the threshold of indices. Therefore, water surface in the 2011 scene was falsely classified as built-up area and correctly classified as water again in the 2016 scene, leading a change of built-up area into water surface.

The conversion of built-up area in 2011 into vegetation in 2016 is an error caused by cloud coverage. The scenes in 2011 exhibited dense cloud coverage towards the west of the river basin. Given that clouds have similar reflectance to built-up area, these pixels were incorrectly classified as built-up area in 2011. In the 2016 scene, the area with cloud coverage was not present, providing the true reflectance value of the underlying land cover, which is vegetation. This phenomenon created the conversion of built-up area into vegetation.

For the time period under consideration, built-up area increased 342.45 km^2. This level of increase is approximately 117% of the target increase stated in the land use master plan of Quang Nam and Da Nang city, indicating that more built-up land has been created than planned. Paddy rice reduction for the time period under consideration is 53.86 km^2, a figure that is greater than the target reduction in the land use master plan. In particular, the level of reduction is 116% of the target reduction (Table 8).

Table 8. Land planning changes in Quang Nam and Da Nang until 2020.

	Planned (2011-2020) (km^2)	Status (2011-2016) (km^2)	Goal reached (%)
Agriculture (rice)	-46.60	-53.86	116
Urban area	+292.57	+342.45	117

The reduction of paddy rice cultivation area is fragmented rather than covering large areas. The spatial distribution of paddy rice conversion area is illustrated in Fig. 7. There appears to be no large-scale paddy rice area reduction but rather smaller-scale reductions at the household level.

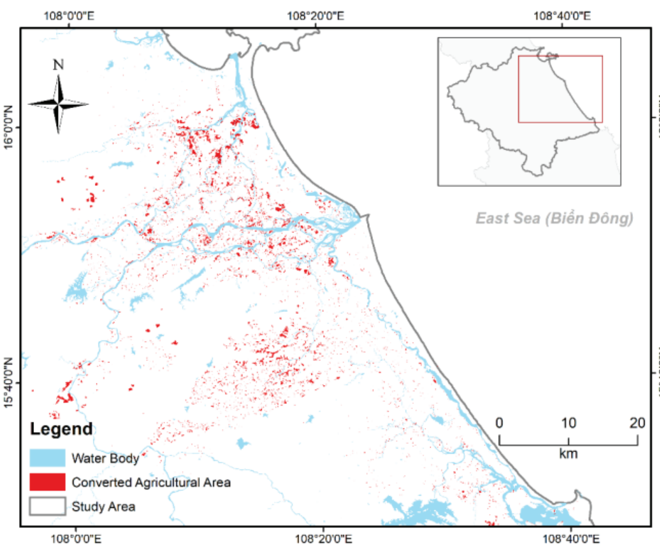

Fig. 7. Paddy rice area converted between 2011 and 2016.

Paddy rice area in 2011 was replaced by built-up infrastructure, water, vegetation, and empty land by 2016. Of the 68.89 km^2 of rice cultivation area converted, roughly 25% was converted into built-up area. A smaller proportion of the conversion of paddy rice land is into water. The remaining majority of paddy rice land conversion was into vegetation and empty land (Table 9).

Table 9. Conversion of agricultural land (units: km^2).

Converted into Built-up	Converted into Water	Converted into Vegetation	Converted into Empty land	Total conversion
10.10	19.12	53.81	30.60	68.89

The conversion of paddy rice into built-up areas took place in Da Nang city and along the Da Nang - Hoi An - Tam Ky connecting route (Fig. 8). Da Nang is growing rapidly, leading to a high demand for urban development. This demand forces agricultural area to be replaced by built-up area. In addition, the conversion of paddy rice along the Da Nang - Hoi An - Tam Ky connecting route is a direct result of urbanization.

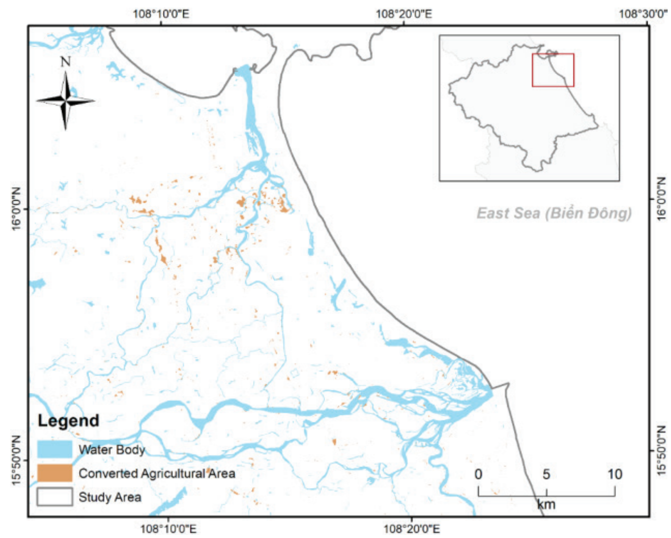

Fig. 8. Conversion of agricultural area into built-up area.

The conversion of agricultural land into built-up area could be assessed in relation to the socioeconomic development of the river basin in the same period. This study utilizes four socioeconomic indicators for the assessment, including: average monthly income (million Vietnam dong - VND), average population (inhabitants), gross output of economic sector (VND), and gross domestic product share by economic sector (%). The values of the indicators were taken from the Statistical Yearbook of Quang Nam in 2011 and 2015 [28, 29]. The selection of 2015 as the end period instead of 2016 is due to the nature of the statistical yearbook and land cover classification scheme. Land cover classification was performed for early 2016 while socioeconomic data in 2015 were compiled in early 2016, hence, the overlapping time period provides a better comparison basis.

From 2011 to 2015, average monthly income increased in both rural and urban areas in Quang Nam (Table 10). Average monthly income in the urban area nearly doubled while income in the rural area increased 1.5 times. Nonetheless, the increase in average monthly income of the urban area is slightly higher than in the rural area both in absolute terms (VND) and relative terms (percentage).

Table 10. Average monthly income per capita in Quang Nam province (unit: million VND).

	2011	2015	Change
Urban	1.413	2.585	82.9%
Rural	1.179	1.862	57.9%

Higher income in the urban area could boost an incentive for migration from rural areas to urban areas. In other words, people living in the rural area are attracted by the higher income increase in the urban area and migrated for better living standards. Assessment of migration is performed using population data in Quang Nam Province (Table 11).

Table 11. Population (inhabitants) and birth rate in the VGTB river basin.

	Population			Birth rate		
	2011	*2015*	*Change*	*2011*	*2015*	*Change*
Urban	273,072	356,845	30.7%	9.56%	9.92%	0.36%
Rural	1,161,928	1,123,945	- 3.3%	10.80%	10.79%	0.01%

For the time period under consideration, the urban population increased 30.7% while the rural population decreased 3.3%. This change in urban and rural population could be attributed to either natural increase in birth rate or migration.

It is clear from Table 11 that the birth rate in the urban area is positive while the birth rate in the rural area is nearly zero. Therefore, the increase in the urban population was surely affected by the increase in the natural birth rate. However, the contribution of the birth rate is not as significant as the overall increase in population (30.7% versus 0.36%). Therefore, migration of people into the urban area clearly was a more significant contributor. On the other hand, the reduction in population in the rural area could not be attributed to a stagnant birth rate; in fact, the rural birth rate neither increased nor decreased during the time period. Therefore, the decrease in rural population could only be a direct result of mass movement.

The migration pattern from rural to urban is fairly common in rapidly urbanizing areas. This migration pattern could trigger spikes in real estate prices due to the principle of supply and demand. A quick analysis of land prices in Da Nang city for the period of 2011-2015 revealed an increase of as much as 35% with an average price increase of approximately 18% [30, 31].

The gross product in agriculture and industry in Quang Nam province increased significantly for the time period of 2011-2015 (Table 12), more than doubling in both sectors with a slightly higher increase in industry. The measure of gross output is in VND.

Table 12. Gross output and contribution of agriculture and industry (unit: million VND).

	Gross output			Contribution		
	2011	*2015*	*Change (%)*	*2011 (%)*	*2015 (%)*	*Change (%)*
Agriculture	7,829,380	17,614,624	125.0	20.7	16.4	- 4.3
Industry	28,845,598	75,044,064	160.2	40.5	43.2	2.6

Although the gross output of agriculture more than doubled, its share within Quang Nam's economy decreased slightly (4.3%). This contradicts the increase in share of industry for the same period (2.6%). The values are illustrated in Table 12. Without being too presumptuous, a shift in the economic structure of Quang Nam from agriculture to industry could be deducted and could have implications for land use in the region.

By reviewing the socioeconomic indicators, a number of conclusions could be drawn regarding the conversion of agricultural land into built-up area. *Firstly*, there exists a migration pattern from the rural area to the urban area within the river basin. This is fuelled by better living standards and incomes in the urban area. This migration created a higher demand for urban housing, therefore, more built-up area has been developed to meet the increase in population. *Secondly*, there exists a shift in the economic structure of the river basin. An increase in the industrial share of the economy created higher demand for built-up infrastructure, and a decrease in the agriculture share of the economy reduced demand for agricultural area. Therefore, the conversion of agriculture into built-up area is explained.

The conversion of agricultural land into water bodies occurred only near river streams (Fig. 9). This can suggest two conversion mechanisms. Firstly, paddy rice cultivation land close to river streams has been totally abandoned due to erosion. However, this accounts for only a small proportion of the conversion. The other conversion mechanism is the conversion from cropland to aquaculture. The explanation is somewhat justifiable given that the market value for aquaculture products is higher than the market value for crops, providing incentives to farmers to change their produce. In particular, shrimp prices are approximately 40 times higher than rice (200,000 VND versus 5,000 VND/kilogram) [8]. In addition, the Vietnam Ministry of Agriculture and Rural Development has offered incentives to increase the country's agricultural export value. Thus, more cropland is being converted into fish or shrimp farms (aquaculture).

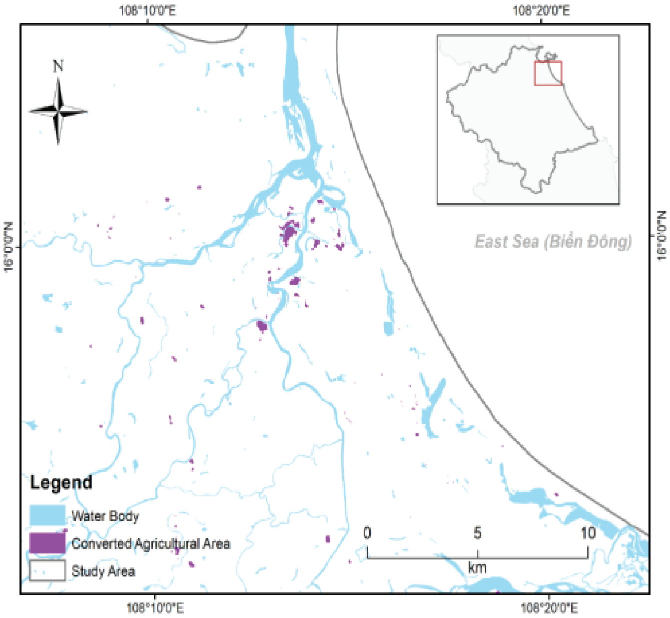

Fig. 9. Conversion of agricultural land into water bodies.

The conversion of agricultural land into vegetation accounts for the majority of agricultural land reduction within the period of 2011-2016. The classification scheme limits the ability to assess the exact type of vegetation into which paddy rice has been converted. One suggestion is that the type of crop cultivated changed from paddy rice to perennial crops. Using the classification method, these areas are green throughout the months used in the multi-temporal NDVI assessment, which would not be expected with paddy rice cultivation techniques. Therefore, these areas would have been occupied by another type of vegetation. The spatial distribution of the conversion of paddy rice into other types of vegetation is illustrated in Fig. 10.

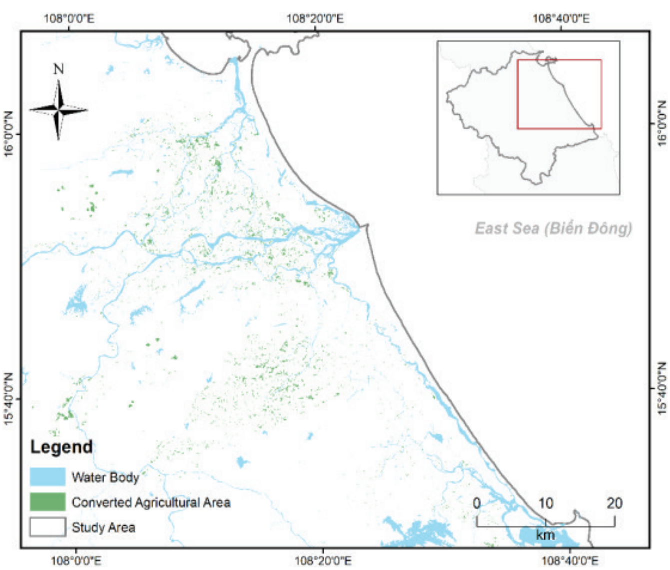

Fig. 10. Conversion of agricultural area into vegetation.

The remaining agricultural land conversion was into empty land. All conversions took place within the city area of Da Nang, which suggests that previously cultivated areas for paddy rice are now abandoned. Given the rapid urbanization pressure discussed earlier, these agricultural areas would have now been converted into built-up area, however, they were still in the process of being developed at the time of the satellite image. An example of the spatial distribution of such conversion is illustrated in Fig. 11.

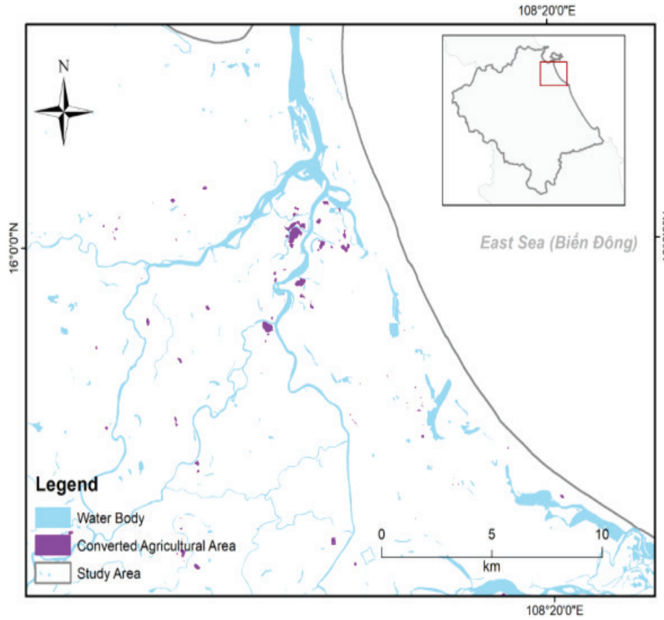

Fig. 11. Conversion of agricultural area into empty land.

Implications of the results

The implications of the land cover change dynamic between agricultural and non-agricultural uses in the VGTB river basin are manifold. They include reassessment of the land use master plan target, measures to regulate housing development, the nature of the mechanism of paddy rice conversion, assessment of aquaculture development in agriculture, and improved market conditions for newer agriculture crops.

Firstly, the increase in built-up area has reached its target four years ahead of schedule. Consequently, further development must be delayed to ensure that no additional increase in built-up area will take place over the coming years. Given that there are another three years until the end of the land use master plan period, there is a chance that further development would violate the target for the built-up area. That is to say, if the land use master plan is to be adhered to at all costs, no further land development would be allowed to take place in the following years. Therefore, policymakers are faced with two options: either strictly enforce the target for the increased built-up area or revise the target.

Secondly, the increase in built-up area, especially housing development, should be placed under scrutiny and regulation with the purpose of avoiding a housing market bubble. The increase in built-up area as evaluated earlier is due to better development opportunities as well as land use policies. Given the incentives both by policies and financial reward, the market would further create pressure to utilize undeveloped land and convert it into built-up areas. However, an overabundance of housing could backfire, creating a housing market bubble and speculation. The consequence of a bubble burst could be fatal to current and future development.

Thirdly, the paddy rice cultivation area decreased according to the master plan, however, it was not converted into built-up area but rather into other types of agricultural uses. This suggests another mechanism in play preserving paddy rice (agricultural) land from urbanization. Given the financial incentives of converting agricultural land into built-up area, one question arose: Why has only a small portion of paddy rice been converted into built-up area while the increased built-up area target has been met? The answer could be found in the Land Law of 2013 [32]. In particular, clause 57 maintained that conversion of agricultural land into built-up area must be approved by the local government, therefore, discouraging such conversion. Moreover, one could also view the question in terms of people's livelihood. Agriculture remains the backbone of the local economy, hence, people would rather keep their land and replace rice with higher-value products such as perennial crops and aquaculture rather than selling their land for urban development.

Fourthly, the conversion of paddy rice area into aquaculture could have a non-reversible effect on the use of land in the future. Aquaculture close to a coastal zone would normally be in the form of saline-adaptive species. Therefore, once paddy rice fields have been converted into fish or shrimp farms, reverting back to paddy rice would require much effort to remove soil salinity. Aquaculture near the coast in general, and fish and shrimp farms in particular, require the construction of ponds of sea water. Once sea water has been introduced, the soil eventually becomes saline due to evaporation. Therefore, reverting back to paddy rice fields from aquaculture can be challenging. This would require a large amount of effort to improve the soil quality and to reduce soil salinity levels to a threshold acceptable to a rice crop. Therefore, the conversion of paddy rice into aquaculture farms must be undertaken cautiously as it represents a non-robust conversion mechanism.

Finally, the conversion of land for paddy rice cultivation into land for other types of crops or aquaculture must be viewed with the overall economy in mind. The nature of rice allows the product to be stored for a long period of time and transported to easily accessible markets both domestically and internationally. The same is not true for other types of crops and aquaculture products. Fruits, for example, cannot be stored for periods longer than weeks. Hence, the market for newer agricultural products in the region has to be thoroughly assessed and accessibility must be improved. Failure to do so will result in an overabundance of products that are unable to reach consumers, creating socioeconomic problems in the river basin.

Conclusions

Land use policy has been evaluated in this study through the use of GIS and remote sensing technologies. Land cover maps for 2011 and 2016 were produced using an index-based classification approach. The 2011 map represented land cover prior to the current land use master plan while the 2016 map represented land cover after the master plan was adopted.

Land cover change detection between 2011 and 2016 revealed an increase in built-up area and a decrease in agricultural (rice) area. Built-up area in 2016 met its target four years ahead of schedule, indicating a rapid urbanization process. Agricultural area (rice area) also met its target in 2016. However, the conversion of agricultural area has largely been a conversion between types of crops and to aquaculture. To a smaller extent, there has also been conversion from agricultural area into built-up area.

The implication of these results could be used to better understand the impacts of land policies in the river basin. By understanding the resulting effect of the policies, adjustments could be made to the current land use policies and lessons could be learned to apply to future policies. This is especially important since not all policies worked out according to their intended purposes; socioeconomic factors may contribute to the deviation from the land use policies.

However, this study is not without limitations and room for further improvement. Land cover classification in the study could possibly be further improved in a number of ways. This includes utilizing other sources of data such as land use maps from the Vietnam Ministry of Natural Resources and Environment and higher-resolution satellite data such as those from SPOT.

The authors declare that there is no conflict of interest regarding the publication of this article.

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