ASSESSING LAND USE TRANSFORMATION IN AGRICULTURAL REGIONS IN DEVELOPING COUNTRIES: A CASE STUDY OF TIEN GIANG PROVINCE, VIETNAM

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ABSTRACT

The rapid expansion of urban areas caused by increasing population is one of the main factors contributing significantly to Land use/Land cover (LULC) change, especially for places with economic growths. Urbanization is, however, sometimes uncontrolled and requires immediate attention to avoid latter expensive remediation efforts, especially since this phenomenon could lead to the lack of agricultural land resources. This study uses the case study of Tien Giang province in Vietnam to improve our understanding in the transformation of LULC in agricultural economics. By using Maximum-likelihood supervised classification and Urban Index (UI) for Landsat images acquired in 1998, 2009 and 2017, the overall accuracies reached up to 87%, 81% and 83% compared to ground truth data. Results from the study showed remarkable dynamics of LULC in the area. The total area of bare land was over 33,900 ha in 2017, decreased nearly 11,500 ha compared to 1998. Conversely, the built-up land increased tremendously from 3,780 ha in 1998 to over 23,126 ha in 2017, experiencing an increase of 19,000 ha for 19 years. Vegetation cover occupied 170,700 ha in 2017, dropping by 7,367 ha from 1998. The area of water witnessing the least change among the four kinds of LULC decreased just by 554 ha over 19 years. Built-up land such as residential zones or road systems has been responsible for the reduction of vegetation land in the study area. The results from this study can provide local officials and decision makers with essential information about the spatial changes of land use/ land cover over time towards planning land and protecting environment sustainably.

1. INTRODUCTION

Urbanization can be considered as an inevitable process in this century since cities provide greater chances to assess labor markets, transportation, education, housing and health cares. Along with urbanization, agricultural lands were replaced with more modern facilities, traffic infrastructures, and residential and industrial zones (Iheke *et al.,* 2015). Since the world population was expected to reach to about 10–14 billion by the year 2100 (Lutz *et al.,* 2001), urbanization will occur both intensively and extensively. Although scientific evidence indicated that urbanization may help boost economic growth, this process also resulted in negative impacts directly and indirectly. Over recent decades, the global urbanization has magnified a variety of environmental impacts including reduction of farm lands and food security (Iheke *et al.,* 2015; Francis *et al.,* 2013; Pramanik *et al,*. 2010; Lopez *et al.,* 2001), habitat degradation (Alphan, 2003), the decrease in vegetation cover as well as effects of climate change at local, regional and global scales (Grimm *et al., 2000*). Additionally, this process made a lot of remarkable impacts on natural ecosystems as well as their critical functions (Mohan *et al.,* 2011).

Due to rapid economic development and population growth, urbanization has become a common phenomenon. Land conversion is happening in both developing and developed countries (Lichtenberg *et al.,* 2008; Ho *et al.,* 2004). The drivers of agricultural land conversion can be various and different from countries regarded with trends, categories, and intensity (Lichtenberg *et al.,* 2008; Malik *et al.*, 2015). They can be divided into two groups: internal and external. The internal drivers were composed of land productivity, ownership patterns including land size and household size and income. On the other hand, urbanization, socio-economic conditions and government policies were considered as the external factors. Despite many studies have been carried out to emphasize the negative impacts of agriculture land conversion, China, Indonesia, the Philippines, India, and Vietnam have experienced the massive loss of arable land related to the rapid extension of urban areas due to population growth (Malaque *et al.*, 2007; Fazal, 2001; Fir man, 1997). It is essential to assess changes of bare lands, especially in agricultural areas, for soil health prediction or the timing of fallow periods in paddy fields after harvesting (Assyakur *et al.,* 2012). Distinguishing the built-up and bare lands in urban areas is also necessary because they can be considered as an indicator for monitoring urban development and environmental quality (Weng, 2008). In the past, land surveying was, however, an expensive and time-consuming process.

In recent years, remote sensing (RS) becomes an attractive and popular approach to estimate and classify land cover patterns. Satellite images are available and various to monitor land use land cover change over long periods of time. Some prominent application of RS related to LULC included LULC evaluation, assessing the rates of changing in LULC patterns, expansion of urban areas and urban heat islands (Mohan *et al.,* 2011). In addition, the information extracted from RS could help to establish useful statistic data that contribute into sustainable development and planning strategies for urbanization (Verma *et al.,* 2009).

The objective of this study is to classify and map land-use/land-cover of the study area due to urbanization, and to assess the increase in urban land and the decrease in farm land via the case study of Tien Giang province, the Vietnamese Mekong Delta. This province was chosen because it contributed a significant amount of rice production in the country, but urbanization was challenging its sustainable development. In this paper, land use/cover classification characteristics were identified by using Landsat TM and OLI/TIRS images combined with Geographical Information System (GIS).

2. STUDY AREA AND METHODOLOGY

The study was conducted in Tien Giang province in the South of Vietnam (Figure 1). Tien Giang spreads over an area of around 250,830 ha, with a population of 1,677,986 persons. The province is one of the most important transportation hubs in the Mekong Delta, which contributes largely into exchanging of agricultural products and goods between local areas and Ho Chi Minh City as well as other provinces in the Southeast of Vietnam. The major occupation of the rural inhabitants is agriculture, with rice, fruit trees, onion, chives, and maize as their major crops.

The land use/ land cover categories of the study area were classified and estimated for three time periods (1998, 2009, and 2017) with Landsat TM and Landsat 8 OLI/TIRS. All images (path 125, row 052) were downloaded from USGS. The satellite images were chosen according to two criteria: low cloud coverage (<5%) and the same season of agricultural crops (December or January).

Land use mapping often applies the multispectral classification methods both the supervised and unsupervised methods (Li *et al.,* 2014); however, there are many methods using remote sensing indices. Among of them, Urban index (UI) (Kawamura *et al.,* 1996) is a good indicator for parameters of development and urbanization. In this study, UI was estimated by using band 7 and 4 for Landsat TM (1998, 2009); band 7 and 5 for Landsat OLI/TIRS (2017). UI is strongly related to the density of built-up cover. Value levels of UI

(Table 1) were employed to distinguish bare land and built-up land in the study area, showing in the Figure 2.

$$\text{UI} = \frac{\text{SWIR2} - \text{NIR}}{\text{SWIR2} + \text{NIR}} \tag{1}$$

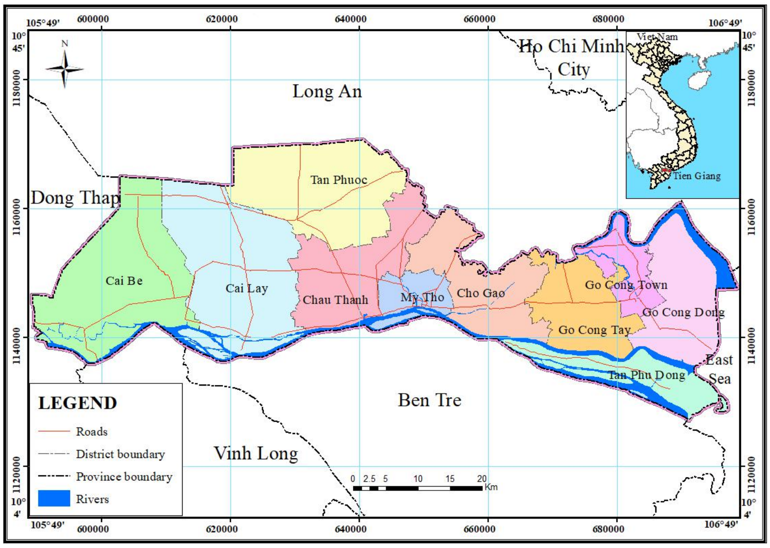


Figure 1. Location map of the study area

Table 1. Ranges of Urban Index in determining built-up and bare land

UI values	Period		
	1998	**2009**	**2017**
Max	0.717172	0.677778	0.51739
Min	-0.966102	-0.900000	-0.601088
Built-up land	> -0.094152	> -0.134710	> -0.117615
Bare land	-0.329364 to -0.094152	-0.309049 to -0.134710	-0.288882 to -0.117615

Water bodies may be mixed with bare land, so the next classification steps should be carried out by combining the true color composite images and Google Earth data. The color composites for the three images were derived from Landsat TM with bands 1, 2 and 3 and Landsat 8 OLI/TIRS with bands 2, 3 and 4. These composited images also assisted to set up sampling sites of each class and mapping LULC for each period. A supervised classification system using maximum likelihood algorithm was consequently used for land use/cover maps in the area, including four classes: bare land, built-up land, water, and vegetation. For this step, sampling sites were carefully chosen that had enough homogeneity to determine the accuracy of classification in each image. To measure the overall accuracy of classification methods and the matching between the classified pixels and the real-world land cover types, the error matrix and kappa coefficient were employed. They have been used in many land classification studies (Pham *et al.*, 2016) and were applied for this research.

3. RESULTS AND DISCUSSIONS

The quality of classification methods was determined by assessing the coincidence of the information derived from remote sensing and truth ground data. The accuracy of the three LULC maps was determined by using random sampling designs and applying the Kappa coefficient. Randomized 120 checking points for each map were selected according to the distribution of land use/cover classes. These pixels were checked with topographic maps, Google Earth data and an interpretation of fieldwork information. The overall accuracies were 87%, 81% and 83% for 1998, 2009 and 2017 LULC maps, respectively.

Population growth and urbanization have led to the increase in built-up land in the area from 3780.09 ha in 1998 to 23126.76 ha in 2017 (a rise of 19346.67 ha; Figures 2 and 3). During the period of 1998 - 2009, built-up land started to grow and covered an area of 3703.59 ha. In the next period (2009 - 2017), there was a sharp increase in the land class from 7483.68 ha in 2009 to 23126.76 ha in 2017. It was clear that the area of My Tho city (location in Figure 1) had significantly expanded in the period and the majority of local traffic infrastructures had been asphalted or cemented.

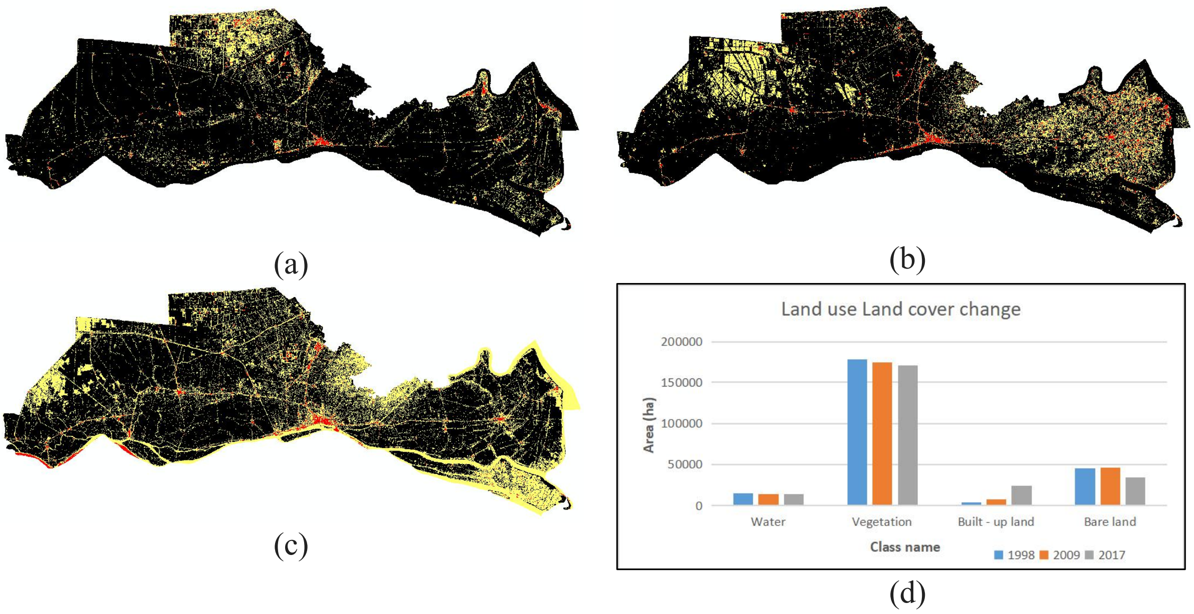
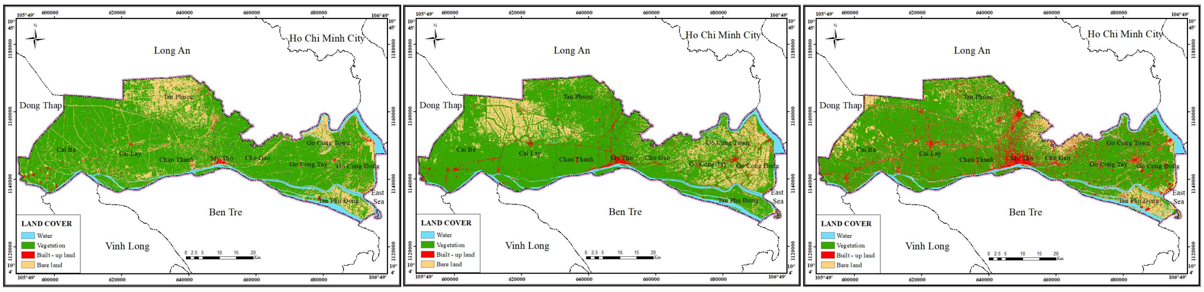


Figure 2. Classified images of bare land and built-up land based on UI (a) 1998; (b) 2009; (c) 2017 (red – build-up area; yellow – bare land; black – other classes) and (d) Changes in land cover classes 1998 - 2017

We found that the reduction of bare land has a tight relationship with the expansion of built-up land, especially in areas were adjacent to My Tho city and along main roads of the province. Bare land, which occupied a large proportion, could be agricultural land for short-term food crops like rice or other fruits and vegetables. However, on the dates when satellite images were acquired, the soil of the areas was exposed because of intermediate stages between crop seasons. The area of bare land from 1998 to 2009 increased slightly about 486.72 ha (from 45,397.35 ha to 45,884.07 ha). This was because satellite images were collected at the time of harvest of some local farm products, and fields could be cleared and exposed. Until 2009, the fields had been planted new crops such as pineapple, rice, and dragon fruit. However, in the next period (2009 - 2017), bare land areas experienced a considerable decrease of 11,911.23 ha, from 45,884.07 ha in 2009 to 33,972.84 ha in 2017. For all the period of 1998 – 2017, bare land area suffered from a rapid reduction of 11,424.51 ha (from 45,397.35 ha – 33,972.84 ha). Vegetation areas considered as areas with long-term fruit trees tended to decrease slightly after 19 years (1998 - 2017). Between 1998 and 2009, vegetation lands decreased by 3,576.96 ha. It continued to decline for the next 8 years from 174,492.72 ha in 2009 to 170,701.74 ha in 2017. For the all 19 years, vegetation cover areas just reduced by 7,367.94 ha. This fall was also due to the development of residential areas.

The water areas were changed very least among the four classes of land cover. It only decreased by 554.22 ha in 19 years.



(a) (b) (c)

Figure 3. Land use land cover distribution over Tien Giang for the years (a) 1998 (b) 2009 (c) 2017

The rapid urbanization in Tien Giang not only reflected its economic growth but also population booming. However, uncontrolled and unappropriated land transformation could impact enormously on the environment and agricultural sector (Tan *et al.,* 2009). In fact, the balance between urbanization and land conservation has been hotly debated. According to pro-ruralists, land conversion can lead to bad results such as the loss of farm land and effects on food security, decrease in agricultural jobs and abandonment of irrigation infrastructure (Azadi *et al.,* 2011). By contrast, pro-urbanists considered land conversion as a logical consequence of urban growth. Land conversion should not be blamed for the lack of food or poor production in agricultural activities because these problems could be resolved by cutting edge technologies.

4. CONCLUSION

Tien Giang province was dominated with the agricultural economy; but in the current years, urbanization in the area tended to increase that could lead to the transformation from farm land to non-agricultural use land like built-up areas. The reduction of arable land may result in a strong impact on the natural processes, local economy, and agricultural activities. For 19 years (1998 - 2017), there was a decrease in vegetation cover (7367.94 ha) and an increase in built-up land (an increase of 19346.67 ha). The area of vegetation occupied the largest area over the all years with orchards, rice and vegetables. The total area of bare land was over 33,900 ha in 2017, decreased nearly 11,500 ha compared to 1998. Built-up land was expanded strongly because of the development of residential zones like My Tho city or some other towns and the improvement of local traffic transportation. Nevertheless, since localized development may pose more pressures on sustainable development of the region besides regional impacts (Dang *et al.*, 2018), further studies on negative impacts of urbanization are required.

5. REFERENCES

Alphan, H., 2003. Land Use Change and Urbanization in Adana, Turkey. *Land Degradation and Development,* Vol. 14, No. 6, 575-586.

Azadi, H., Ho, P., and Hasfiati, L., 2011. Agricultural land conversion drivers: A comparison between less developed, developing and developed countries. *Land Degradation and Development*, John Wiley & Sons, Ltd.

Dang, T.D., Cochrane, T.A., Arias, M.E., 2018. Future hydrological alterations in the Mekong Delta under the impact of water resources development, land subsidence and sea level rise. *Journal of Hydrology: Regional Studies*, 15, 119-133.

Fazal, S., 2001. The need for preserving farmland: A case study from a predominantly agrarian economy (India). *Landscape and Urban Planning,* Vol. 55, Issue 1, 1-13.

Francis, Z.N., Dinye, R.D., and Kasanga, R.K., 2013. Urbanization and its Impact On Agricultural Lands in Growing Cities in Developing Countries: A Case Study Of Tamale In Ghana. *Modern Social Science Journal*, Vol.2, No.2, 256-287.

Grimm, N.B., Grove, J.M., Pickett, S.T.A., and Redman, C.L., 2000. Integrated Approach to Long-Term Studies of Urban Ecological Systems. *Bioscience*, Vol. 50, No. 7, 571-584.

Ho, S. P. S., and Lin, G. C. S., 2004. Converting Land to Nonagricultural Use in China's Coastal Provinces: Evidence from Jiangsu. *Modern China,* Vol 30, Issue 1, pp. 81 - 112.

Iheke, Raphael, O., and Ukandu, I., 2015. Effect of Urbanization on Agricultural Production in Abia State. *International Journal of Agricultural Science, Research and Technology in Extension and Education Systems,* Vol.5 No.2, 83-89.

Kawamura, M., Jayamana. S., and Tsujiko, Y., 1996. Relation between social and environmental conditions in Colombo Sri Lanka and the urban index estimated by satellite remote sensing data. *Remote Sensing,* Vol. 31, 321–326.

Li, S., and Chen, X., 2014. A new bare - soil Index for rapid mapping developing areas using Landsat 8 data. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XL-4. 6 pages.

Lichtenberg, E., and Ding, C., 2008. Assessing farmland protection policy in China. *Land Use Policy,*Vol. 25, Issue 1, 59-68.

Lopez, E., Bocco, G., Mendoza, M., and Duhau,E., 2001. Predicting Land Cover and Land Use Change in the Urban Fringe a Case in Morelia City, Mexico. *Landscape and Urban Planning*, Vol. 55, No. 4, 271-285.

Lutz W., Sanderson W., and Scherbov S., 2001. The end of world population growth. *The Nature* vol. 412, 543–545.

Malaque, I.R., and Yokohari, M., 2007. Urbanization process and the changing agricultural landscape pattern in the urban fringe of Metro Manila, Philippines. *Environment and Urbanization,* Vol. 19, issue: 1, 191-206.

Malik, R., and Ali, M., 2015. The Impact of Urbanization on Agriculture Sector: A Case Study of Peshawar, Pakistan. *Resources Development and Management* Vol.8, 79 - 86.

Mohan, M., Pathan, S.K., Narendrareddy, K., Kandya, A., and Pandey, S., 2011. Dynamics of Urbanization and Its Impact on Land-Use/Land-Cover: A Case Study of Megacity Delhi. *Journal of Environmental Protection*, vol.2, 1274-1283.

Pham, L.T.H., Brabyn, L., Ashraf, S., 2016. Combining QuickBird, LiDAR, and GIS topography indices to identify a single native tree species in a complex landscape using an object-based classification approach. *International Journal of Applied Earth Observation and Geoinformation 50,* 187-197.

Pramanik, C., Dey, S.K., and Sarkar, A., 2010. Effect of Urbanization on Agriculture: A Special Scenario on Andhra Pradesh, Indian. *International Journal of Applied Science and Computations*, Vol.17, No.2, 121-128.

Tan, R., Beckmann, V., Berg, L.V.D., Qu, F., 2009. Governing farmland conversion: Comparing China with the Netherlands and Germany. *Land Use Policy*,Vol. 26, Issue 4, 961-974.

Verma, R., Kumari, K.S., and Tiwary, R.K., 2009. Application of Remote Sensing and GIS Technique for Efficient Urban Planning in India. *Geomatrix Conference Proceedings*, IIT Bombay, 2009.

Weng, Q., 2008. Remote Sensing of Impervious Surfaces: An Overview. In Remote Sensing of Impervious Surfaces. *CRC Press, Taylor & Francis Group: Boca Raton, FL, USA*.