Change monitoring of a heterogeneous urban landscape using RapidEye data – DaNang, Vietnam

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Abstract: Rapidly changing urban agglomerations in developing and emerging countries face social and environmental challenges. Urban population growth and socioeconomic developments manifest in changes in the existing built-up areas as well as in the land use of the urban-rural transition zone. For the City of DaNang, five RapidEye scenes for the years 2010 to 2015 were analyzed. Object-based image analysis was applied to each scene. After segmentation, the image objects were classified based on their spectral properties as well as their spatial and shape-related attributes. Nine classes (water body, vegetation, clouds, built-up area, transportation infrastructure, construction sites, beach, river banks and bare land) were classified based on a rule-based classification approach, as well as support vector machines. For the detection of land-cover change, a pixel based post-classification approach was used to quantify land-cover changes from one class to another. Overall classification accuracies of 73 to 80% were achieved for the five multitemporal scenes. The results indicate that by 2015, the area used for traffic infrastructure and buildings has increased by 24.9 km² (17.7 %) compared to 2010. The newly built-up areas were largely developed on land previously classified as: bare land (54.7 %), vegetation (34.4 %), and on existing construction sites (6.9 %).

Keywords: Remote Sensing, RapidEye, Urban, Land-Cover, DaNang

1 1 Introduction

Rapidly changing urban agglomerations in developing and emerging countries face social and environmental challenges. Urban population growth and socioeconomic developments manifest in changes in the existing built-up areas as well as in the land use of the urban-rural transition zone. The City of DaNang is the largest city in Central Vietnam with a population of more than 1 Mio. Its population is predicted to reach 1.6 million by 2020 [GSO 2011, Ostojic *et al.* 2013, GSO 2014]. The economic growth rate of DaNang is constantly higher than 10 % since the year 2000, resulting in significant investments in the cities infrastructure [DaNang 2012]. The peri-urban districts of the city are experiencing a rapid land conversion. Strong touristic development leads to dynamic building activity along the eastern beach of the city. Industry and technology parks are being created. Flooding and natural disasters, as well as a strong investment in mid- to high-income development projects led to the resettlement of poor households. While the pressure on undeveloped land is increasing, the city administration aims to protect and manage vulnerable ecosystems, such as the Ba Na forest zone and the Son Tra peninsula. Hence, qualitative and quantitative information on the land use development is necessary to provide reliable and continuous data for spatial planning processes. Multi-temporal RapidEye data provide the possibility of change detection of the land use and monitoring of protected areas.

Object based image analysis (OBIA) is a method to analyze remotely sensed imagery and is a well-established method to gain information about land use and land cover (LULC) characteristics from high resolution imagery [Blaschke 2010, Myint & Stow 2011, Blaschke *et al.* 2014]. In contrast to traditional pixel-based methods, several pixels are grouped together to form meaningful image objects as the basic unit for the subsequent classification process [Blaschke *et* *al.* 2014]. The classification of complex and heterogeneous urban and peri-urban landscapes benefits from not only using spectral information, but also contextual parameters such as spatial relationships, geometric and textural information. Several studies showed that the object-based method produced considerably higher overall accuracies as compared to traditional pixel-based classifications when using data from high resolution imagery [Doxani *et al.* 2008, Myint *et al.* 2011, Myint & Stow 2011, Dupuy *et al.* 2012, Li & Shao 2013].

The Objective of this study is to apply object-based image analysis to a multitemporal RapidEye dataset to distinguish between different areas of land use and land cover in order to analyze changes in the urban and surrounding peri-urban areas of Da Nang between the years 2010 and 2015.

2 Study area

Da Nang is situated on the coast of the Eastern Sea and is the largest city in central Vietnam with a population of just over 1 Million people [GSO 2014]. It has a tropical monsoon climate with annual temperatures averaging 25,7 °C.

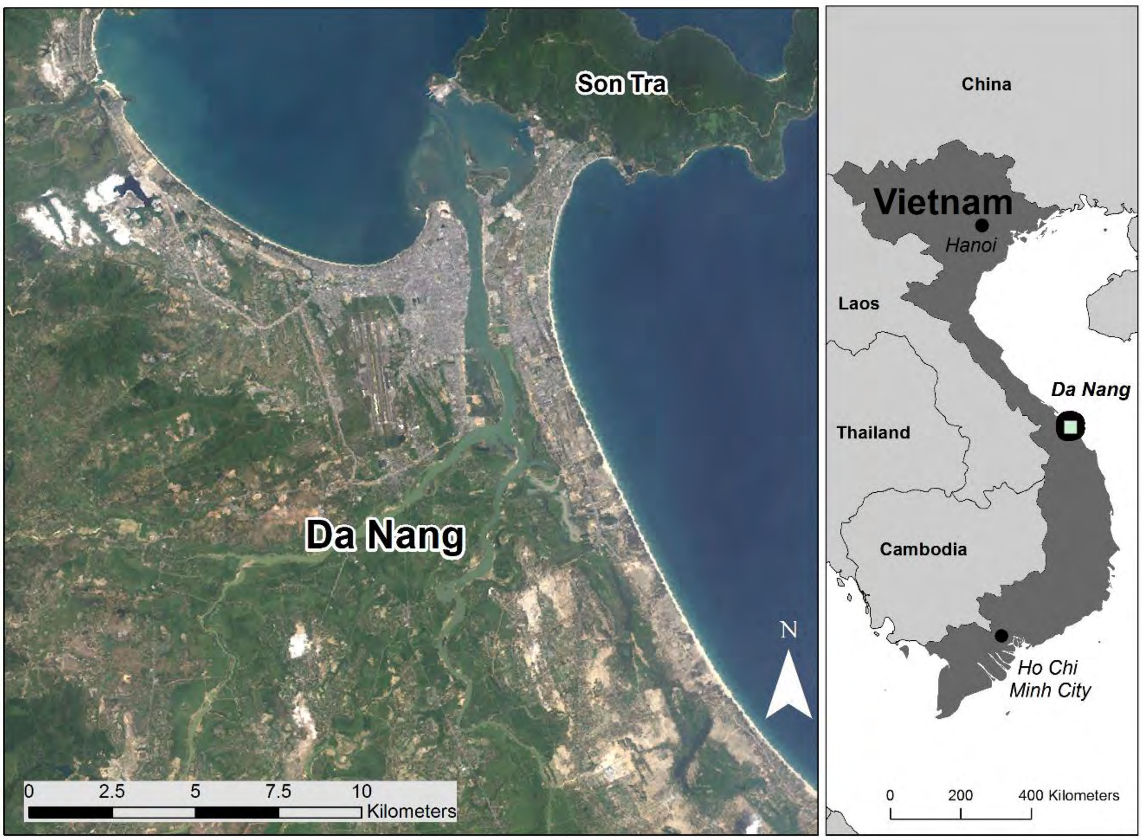

Figure 1. Study area.

The most densely populated district of Da Nang is Hai Chau. The settlements are generally concentrated at the coast, yet for the last decades a rapid growth into its fringes mainly in the other four districts is documented [World Bank 2011]. A special case is the high class living and touristic development close to south-eastern coastline in direction to Hoi An. Constraints of the growth are set by the inner city airport, the coast in the east and southeast, as well as the topography in the north and northwest. Two RapidEye scenes make up the extent of the study area of 25 by 50 kilometers, including the urban and peri-urban built-up areas of Da Nang city as well as large portions of the surrounding forested mountains and the Eastern Sea (Fig. 1).

3 Data and Methods

3.1 Data

Five RapidEye scenes (05/05/2010; 04/20/2012; 04/04/2013; 03/02/2014 and 04/02/2015) were acquired with processing level 3A and a resampled spatial resolution of 5 meters. The images consist of five spectral bands (blue, green, red, red edge and near infrared), the radiometric resolution is 12 Bit. For the accuracy assessment, satellite imagery from different sensors (WV-2 and Geo-Eye1) as well as Google Earth, with higher spatial resolution than the RapidEye imagery, served as reference datasets.

3.2 Research Methodology

Relative radiometric normalization was conducted on the scenes using the Iteratively Reweighted-Multivariate Alteration Detection (IR-MAD) method [Canty *et al.* 2004]. The algorithm selects invariant pixels for bi-temporal image pairing. The RapidEye scene acquired in 2010 served as the reference scene. Subsequently, an object-based image segmentation was applied to each scene. The objects were then classified based on both their spectral properties as well as their spatial and shape-related attributes to distinguish between 9 classes (water body, vegetation, clouds, built-up area, transportation infrastructure, construction sites, beach, river banks and bare land). For the most part, expert knowledge was applied in a rule-based classification approach. Due to highly similar spectral properties, the distinction between some very bright areas of bare land and built-up area proved to be difficult. Here, a support vector machine (SVM) algorithm was applied. For each individual scene, training samples were selected to train the algorithm to distinguish between both classes. For the detection of LULC change, a post-classification, pixel-based approach was used to quantify changes from one class to another on a per area basis between each consecutive year and for the entire period between 2010 and 2015. As a result, a detailed matrix shows the changes (in hectares) from and to each class. Results are also produced in raster format so that the spatial distribution of these changes may be illustrated in change maps. The accuracy of the classifications was tested using a total of 450 stratified randomly selected reference points. A confusion matrix was produced to identify the nature of each misclassification. To minimize the effect of seasonal differences in vegetation, only reference material recorded within 3 months of the original image date was used.

4 Results and Discussion

The results of the change detection indicate that within 5 years, built-up area has increased by 12 % from 140 km² to 157.2 km² (Fig. 2). Most of the additional built-up area that developed by 2015 was classified in 2010 as bare land (55 %), vegetation (34 %), construction sites (7 %) or as water (1.5 %). The area under construction varies between 10 and 18 km². The area used for transportation infrastructure increases constantly. The change matrix as well as the change detection raster datasets contain detailed information about changes from and to each class. This provides a basis for selective analysis to investigate changes specific to a certain class. The inconclusive high value for built-up area in 2012, might result from confusion with bare land and from the influence of clouds and haze.

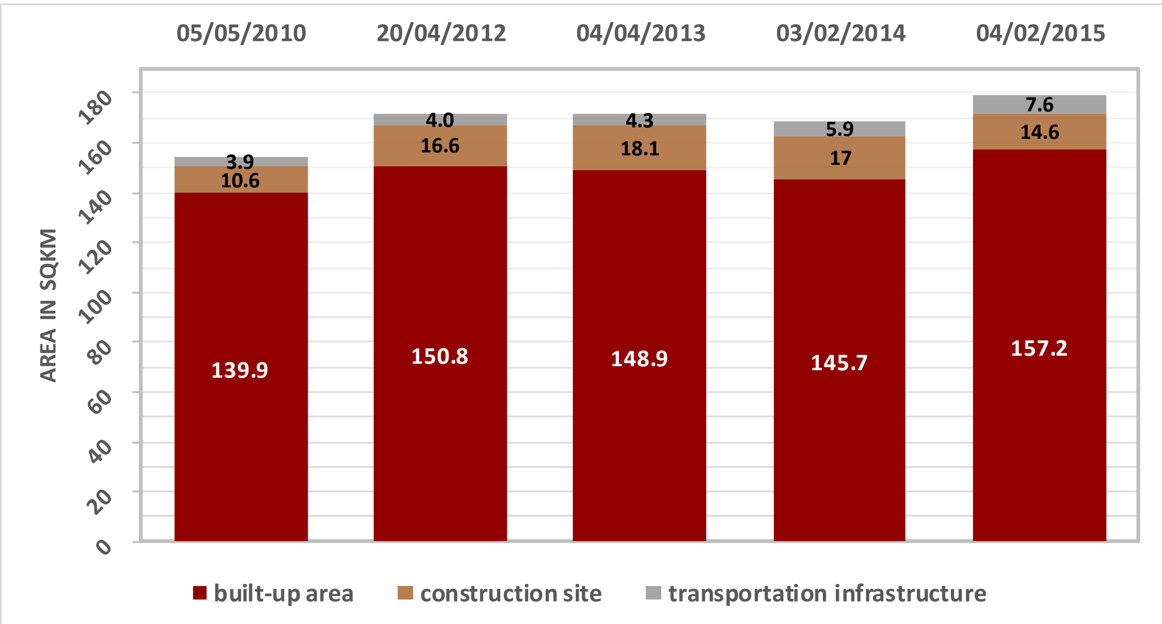

Figure 2: Development of built-up area, traffic infrastructure and construction sites from 2010 to 2015.

The change detection analysis shows strong ongoing building and transport infrastructure developments in the northwestern part of the study area, with a main emphasize on big development areas (Fig. 3). Along the eastern coastline, strong building activities took place. Here we assume that most of the projects are related to the tourist industry. Strong development activities can also be found in the Cam Le district, in the southeast of the airport. The Da Nang-Quang Ngai Expressway Development Project in the south of the study area was identified by the change detection analysis.

Overall classification accuracies range between 73 % for the scene from 2014 and 80 % for the scene recorded in 2012. Most accurately classified were the classes water, beaches and river banks. The lowest accuracies were achieved with the classes bare land, construction sites and built-up area. One source of error was that bare land and built-up were often confused due to similar spectral properties. The delineation of both classes was improved by applying supervised

SVM classification. Cloud cover was negligible in the 2010, 2013 and 2015 scenes, and thus does not impair change detected between 2010 and 2015. However, in 2012 and 2014, 8 % and 2.5 % of total area was covered with clouds. For these areas, LULC information of the following year was used, in order to produce comparable statistics.

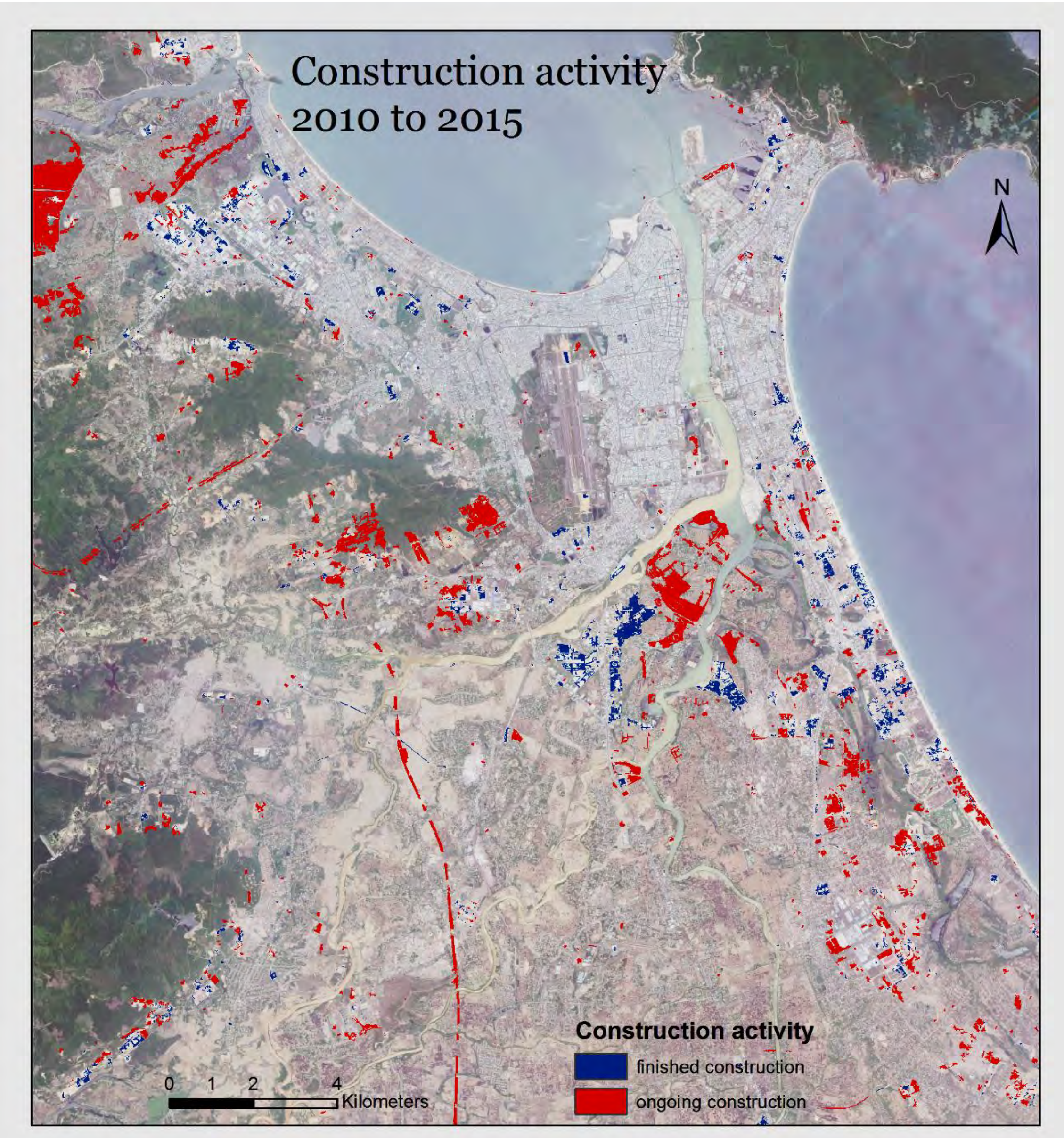

Figure 3: Construction activity in DaNang from 2010 to 2015.

The transferability of the classification from the reference image to the subsequent images is robust, but needs some adjustments for threshold parameters. Although the applied radiometric normalization procedure improves the comparability between scenes, the persisting spectral variation of the same class in different scenes requires the rulesets to be individually modified. This might be largely due to seasonally dependent vegetation cover at the time of image acquisition, ranging from March to May. The change detection reflects the general developments of the city. It identifies clearly the investments in infrastructure and the residential expansion. The main land use change is from agricultural managed and undeveloped to built-up areas. The area identified for transportation infrastructure is underrated. This results from the low image resolution in relation narrow inner city roads, as well as the object oriented methodology. Conversely, the built-up area is probably overrated by the same magnitude.

5 Conclusions

The change detection analysis shows the development of LULC in DaNang between 2010 and 2015. Despite the difficulties encountered with differentiating built-up structures from their spectrally similar surroundings such as bare land, the results obtained from the object-based classification and the subsequent post-classification change detection are contributing to the understanding of LULC change dynamics in the Da Nang area. Furthermore, it provides a basis for further research concerning class specific changes on smaller spatial scales. For more specific information about LULC and LULC change, satellite images with a higher spatial resolution are necessary.

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Theo dõi biến động cảnh quan đô thị không đồng nhất bằng dữ liệu RapidEye – Tp. Đà Nẵng, Việt Nam

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Tóm tắt: Các đô thị lớn có tốc độ phát triển nhanh tại các quốc gia mới nổi và đang phát triển phải đối mặt với nhiều thách thức về xã hội và môi trường. Tăng trưởng dân số đô thị và phát triển kinh tế - xã hội có thể nhìn thấy thông qua những đổi thay ở những khu vực đã được xây dựng nhiều cũng như trong việc sử dụng đất ở những khu vực đang chuyển đổi từ nông thôn sang đô thị. Đối với thành phố Đà Nẵng, năm khung cảnh RapidEye trong giai đoạn 2010-2015 đã được phân tích. Đối với mỗi khung cảnh đó chúng tôi áp dụng phương pháp phân tích hình ảnh dựa trên đối tượng. Sau khi phân đoạn, các đối tượng hình ảnh được phân loại dựa trên các tính chất phổ cũng như các thuộc tính không gian và hình dạng. Sử dụng phương pháp phân loại dựa trên quy tắc cũng như các công cụ vector hỗ trợ đã phân loại được thành 09 loại (khối nước, rừng và đồng cỏ, đất nông nghiệp, mây, khu vực đã xây dựng, hạ tầng giao thông, công trường, bãi biển, bờ sông và đất trống). Để tìm hiểu sự thay đổi của lớp phủ mặt đất, chúng tôi đã sử dụng phương pháp hậu phân loại dựa trên điểm ảnh để lượng hóa những biến động của lớp phủ từ loại này sang loại khác. Mức độ chính xác nhìn chung đạt được ở mức 73-80% đối với năm khung cảnh đa thời gian. Kết quả cho thấy đến năm 2015, khu vực sử dụng làm hạ tầng giao thông và công trình xây dựng đã tăng 24,9km^2 (17,7%) so với dữ liệu nghiên cứu của năm 2010. Khu vực xây dựng mới chủ yếu là khu vực trước đây được xếp vào loại: chưa sử dụng (54,7%), đất trồng trọt (34,4%) và các công trường đang xây dựng (6,9%).

Từ khóa: Viễn thám, RapidEye, Đô thị, Lớp phủ, Đà Nẵng