Brief for GSDR 2015

An Application of NASA MODIS Remote Sensing Images to A Comprehensive Estimation of Ecological Impacts of Urban Development

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Introduction

United Nations (2014) predicts that the share of global urban population will increase from 50 % today to approximately 70 % by 2050. Alongside with this rapid urbanization of the human society, it is estimated that, by 2030, cities will physically expand by 1.2 million km^2, which is almost same size as the Republic of South Africa (Seto, Güneralp, and Hutyra 2012). While this outstanding growth of cities can contribute to more economic growth as well as mitigation of global warming by promoting law-carbon, sustainable, and climate-resilient city development (Grimm et al 2008; Rosenzweig et al 2010; Hodson & Marvin 2010; Ho et al 2013), rapid physical expansions of cities at the expense of vegetation will not only decrease CO^2 absorption capacity of the planet but also vitiate global ecosystem services (Seto, Güneralp, and Hutyra 2012).

Thus, in order to make evidence-based policies for future sustainable cities, one of the important tasks is to grasp accurate and comprehensive pictures of urban expansions and their impacts on surrounding environments. However, quality of data about urban expansions is not always same in all countries, political, or institutional bodies. This can be due to the lack of financial and human resources for urban surveys, the lack of comprehensive observation of the urban area, and/or arbitrariness of administrative borders (such as size and definition). In this sense, developing cheaper, easier, more comprehensive, and more objective ways of observing urban expansions and estimating their impacts is quite significant for development of sustainable urban policies. This brief introduces one of such methods, which utilizes Moderate Resolution Imaging Spectroradiometer (MODIS) images provided by National Aeronautics and Space Administration (NASA) and Geographical Information Systems (GIS). This brief first explicates the method, secondly shows its application to the case of Iskandar Malaysia urban project, Johor Bahru (J.B.), Malaysia, then concludes the entire discussion with exploring challenges of the method.

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Method

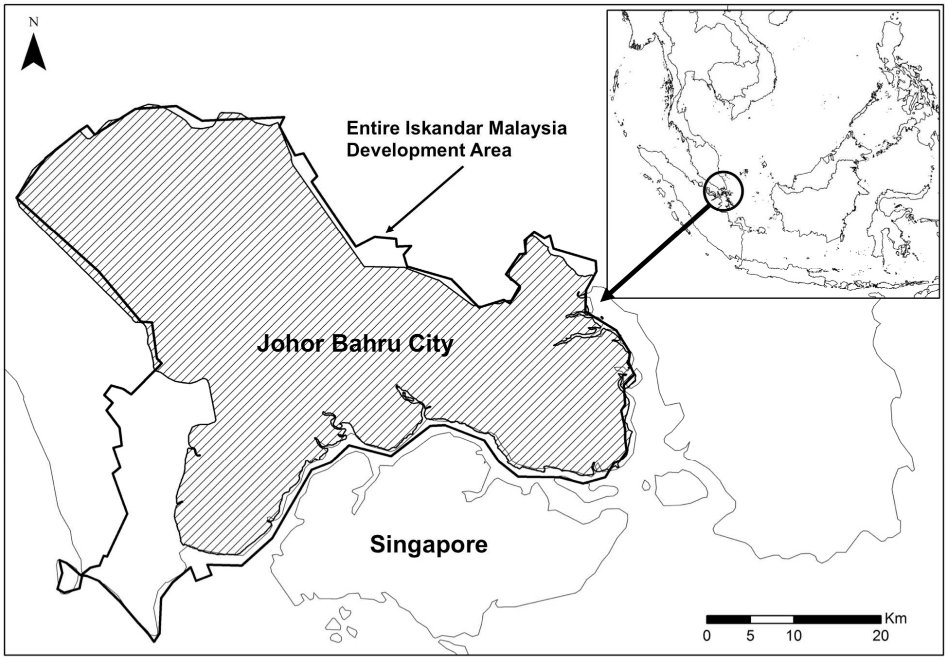
NASA provides many MODIS data products observing different features such as land cover, atmospheric aerosol, total precipitable water, etc[1]. We can utilize these scientifically reliable and comprehensive data sets free. In the method, "MOD 13 - Gridded Vegetation Indices (NDVI & EVI)" data is utilized. This set of remote sensing images enables us to study global-wide vegetation changes with 250-m^2 spatial resolution and 16-day temporal resolution during 2000 and 2013 (currently). This data set contains two different indices: Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI). Although these two indices are complement each other (Vegetation Index & Phenology Lab n.d), EVI has some advantages over NDVI such as reduction of atmospheric distortion and sensitivity for slight vegetation change (Solano et al 2010). Thus, the method uses EVI images. After all images have been downloaded using MODIS Reprojection Tool Web Interface (MRTWeb[2]) with required treatments, raw images are processed by Esri's ArcGIS software[3] in order to retrieve EVI values of the target areas of your study. The retrieved EVI values are easily processed by Microsoft Excel in order to conduct statistical studies.

Although it is useful to simply see time-series change of EVI in the *entire* targeted urban area where the policy makers would like to focus their attention, it can be more useful to make urban policies if a target zone of urban developments (e.g., "Urban Promotion Zone," "Special Development District," etc) is known. This is because we can more clearly estimate how these developments have impacted on the vegetation within the area by contrasting EVI change in the target zone of urban developments with that of other areas. If the developments are done at the expense of the vegetation, you can observe that high values of EVI largely and rapidly decreased in the urban development zone.

Application to Iskandar Malaysia

Iskandar Malaysia project (IM) is a massive urban development project ongoing in J.B. and its neighboring areas situated in the southern tip of the Malay peninsula (Comprehensive Development Plan (CDP) 2006; Rizzo and Glasson 2012. See figure 1). IM started in 2006 and plans to be completed in 2025. The total development area is approximately 2,200 km^2 (CDP 2006). This large development zone contains vegetation that consists mainly of tropical rainforests rich in biodiversity. Several studies warn that IM has been destroying important vegetation of the region, and causing ecological problems such as destruction of biodiversity and water pollution (Nasongkhla and Sintusingha 2013; Hangzo and Cook 2014). However, comprehensive and quantified data about how IM has been impacting on the vegetation of the Johor region is still under investigation. In order to quantify

[1] http://modis.gsfc.nasa.gov/data/dataprod/index.php
[2] https://mrtweb.cr.usgs.gov/
[3] http://www.esri.com/



Map Created by Eigo Tateishi (2015) Lund University. Map Source DIVA-GIS Free Shapefile Data.

Fig 1. Location of J.B. and the designated area of IM

and estimate IM's impact on vegetation, the method introduced in the previous section was applied to the case. By comparing with actual satellite image of the area, in this study, MODIS EVI is classified 1 to 12 different classes[4], where 1 to 3 are no data (or water), 4 & 5 are low vegetation density (could-be urban built-ups), 6 is middle density, and 7 to 12 are high density (See figure 2). Instead of maximum 16-day resolution, 64-day temporal resolution was employed for ease of process. Because IM's Urban Promotion Zone (UPZ) is clarified in the official master plan of the project (CDP 2006), this study contrasts EVI values of the UPZ with that of the entire J.B. Outcomes are shown in figure 3 to 5.

Results and Interpretation

As two maps on figure 3 show, during 2000 and 2013, cells[5] indicating low vegetation (class 4 & 5) increased especially in domain A, B, C, and D. All domains are situated in UPZ, and A, B, and C are designated as "Flagship" development zones where the most active developments are ongoing (CDP 2006).

As the top graph on figure 4 shows, the sum of cells indicating the *high vegetation (class 7 to 12)* both within (A) entire J.B. and (B) UPZ decreased after 2010. More importantly, the difference of the EVI

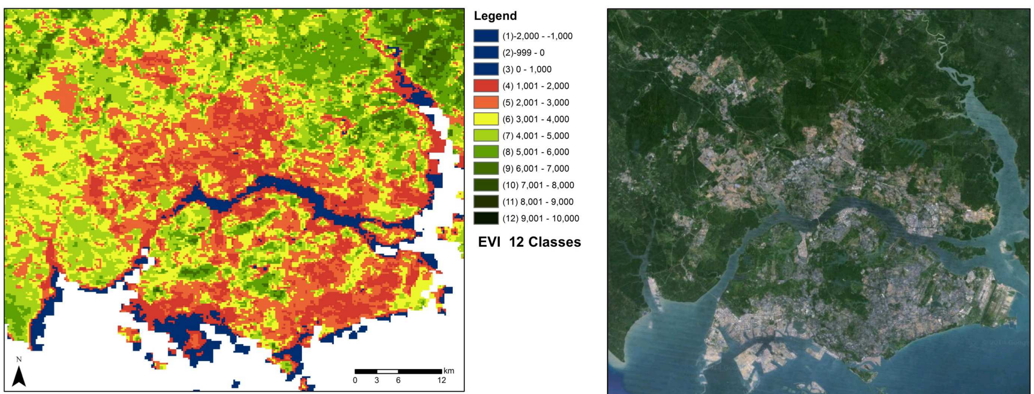
[4] EVI has a valid range of value between -2,000~10,000 (https://lpdaac.usgs.gov/products/modis_products_table/mod13q1). Here, each class has a range of 1000 EVI values, e.g., 1 to 1000 = class-3, 1001 to 2000 = class-4.

[5] 250 m * 250 m

values between (A) and (B) increased after IM started in 2006. As the top graph shows, before 2006, curve (A) and curve (B) are almost synchronized. However, as the bottom graph shows, the gap (EVI of (A) minus that of (B)) started continuously increasing after IM started in 2006.

Figure 5 shows change of area (km^2) by each class and percent change (%) of each class's distribution in the total EVI values during 2000 and 2013. As the figure shows, during 2000 and 2013, within J.B. and UPZ, class 4 and 5 (could-be urban built-ups) increased by 175 km^2 and 183 Km^2 respectively (8.7 % and 15.1 % increase in the share) while the high EVI classes (7 to 12) show outstanding decrease.

These outcomes suggest that construction activities within UPZ have been impacting on the vegetation of the zone.



MODIS 13Q1 (Example: Year 2013 Day321) Map Created by Eigo Tateishi (2015) Lund University.

Actual Land Image of the Area: Retrieved from Google Map (2015 Jan 18th)

Fig 2 shows an EVI map and an actual satellite image of the target region. As you can see, class 4 & 5 roughly correspond to urban built-ups.

Conclusion

The method introduced in this brief enable us to comprehensively study vegetation change in the targeted urban areas in a cheap, easy, and objective (quantifiable) way. In the age of urbanization, to comprehensively and objectively understand ecological impacts of urban expansions is imperative for making policies about sustainable urban developments. As the case study of IM shows, the method can be a powerful tool for the purpose. However, in order to be a more reliable and versatile policy-making tool, it is important to note that the method still has several challenges to be improved:

- **Identifying Urban Developments**
  EVI (NDVI as well) indicates vegetation density, and this cannot distinguish between e.g., barren lands and urban built-ups (both are indicated as "low EVI" such as class 4 to 6 in the method). In order to clarify such differences, other

remote sensing data like nightlight and surface temperature must be combined with the method.

- **Cause and Effect**

  It is not easy to conclude that the decrease of the high EVI values is due *exclusively* to urban developments (the increase of the low EVI values). This is because, as it is pointed out previously, the decrease of the high EVI values is not always explained by urban expansions. Such decrease of low EVI values can be explained by other factors such as climate change, slash-and-burn agriculture, and/or between the decrease of vegetation and urban developments, it is important to discuss why the low EVI values increased, and to check ground truth.

Seasonal Vegetation Change

Seasonal vegetation change (e.g., climate and agricultural) makes it hard to distinguish EVI values. For instance, during winter, an entire target area may show the only low EVI values. Thus, in this example, we must be careful to distinguish between barren lands, urban built-ups, and vegetation without leaves[6]. This challenge also can be improved by combining other remote sensing data.

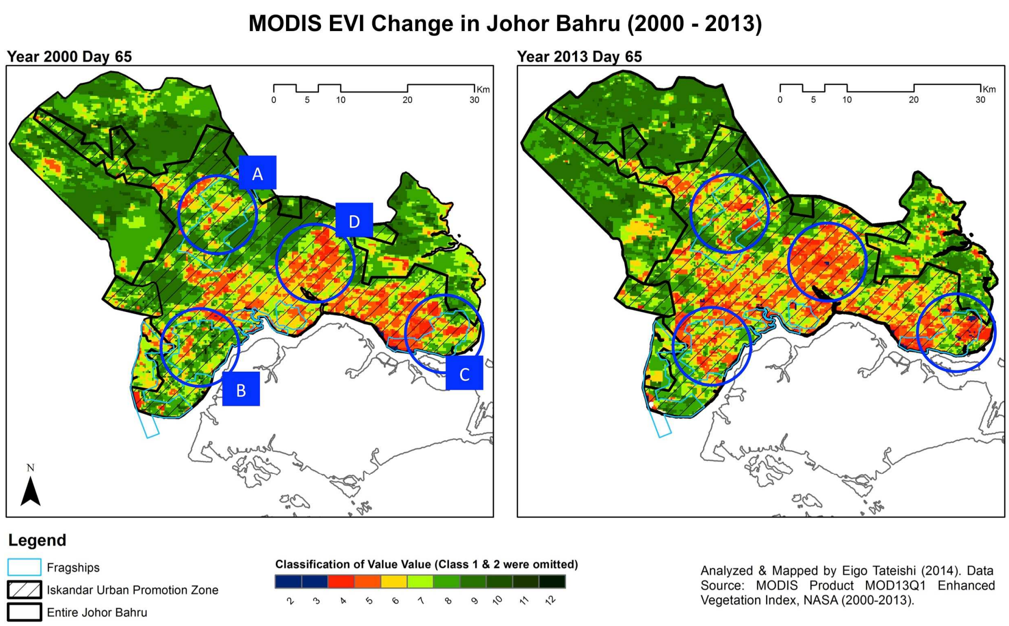


Fig 3. MODIS EVI change in J.B. during 2000 and 2013

[6] Because IM is located in the tropical rainforest climate, this sort of seasonal vegetation change is minimized.

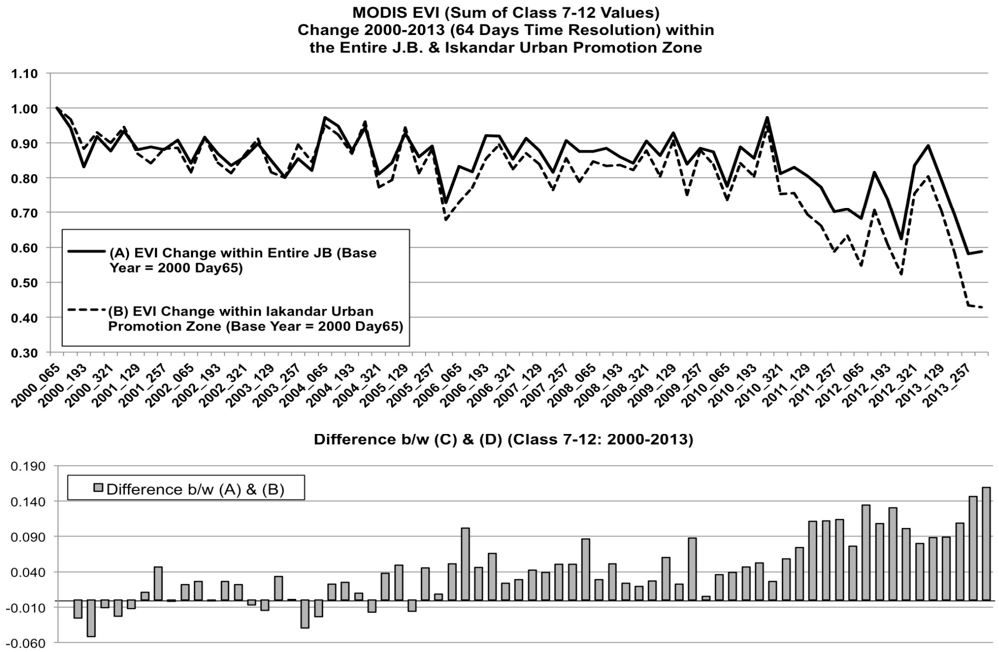


Fig 4. The black curve indicates the sum of class 7 to class 12 EVI values within J.B., and the dot curve does so within UPZ during 2000 and 2013

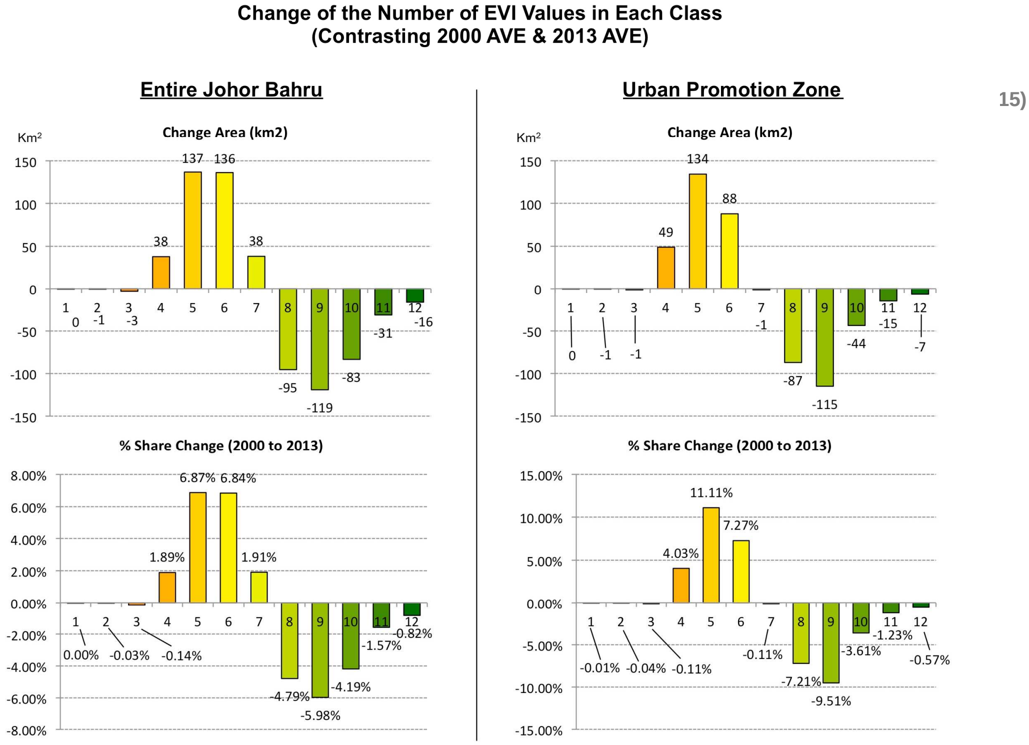


Fig 5. The panel displays actual change of area (km^2) by each class and % change of the share of each class. EVI values for this analysis were attained by averaging EVI values of Day 65, Day 129, Day 193, Day 257, and Day 321 of each class in 2000 and 2013.

References

Collins, J.P. et al., 2000. A New Urban Ecology: Modeling human communities as integral parts of ecosystems poses special problems for the development and testing of ecological theory. American Scientist, 88(5), pp.416–425.

Grimm, N.B. et al., 2008. Global change and the ecology of cities. Science (New York, N.Y.), 319(5864), pp.756–60. Available at: http://www.ncbi.nlm.nih.gov/pubmed/18258902 [Accessed November 6, 2013].

Hangzo, P.K.K. & Cook, A.D.B., 2014. The rise of Iskandar Malaysia : Implications for Singapore ' s marine and coastal, Singapore. Available at: http://www.rsis.edu.sg/rsis-publication/nts/2449-the-rise-of-iskandar-malaysia/#.VL41YWSsUqc.

Ho, C.S. et al., 2013. Low carbon urban development strategy in Malaysia – The case of Iskandar Malaysia development corridor. Habitat International, 37, pp.43–51. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0197397511001159 [Accessed June 11, 2014].

Kahzanah Nasional, 2006. Comprehensive Development Plan: for South Johor economic region 2006-2025.

Nasongkhla, S. & Sintusingha, S., 2013. Social Production of Space in Johor Bahru. Urban Studies, 50(9), pp.1836–1853.

Rizzo, A. & Glasson, J., 2012. Iskandar Malaysia. Cities, 29(6), pp.417–427. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0264275111000382 [Accessed June 3, 2014].

Rosenzweig, C. et al., 2010. Cities lead the way in climate-change action. Nature, 467(7318), pp.909–11. Available at: http://www.ncbi.nlm.nih.gov/pubmed/20962822.

Seto, K.C., Güneralp, B. & Hutyra, L.R., 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proceedings of the National Academy of Sciences of the United States of America, 109(40), pp.16083–8. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3479537&tool=pmcentrez&rendertype=abstract [Accessed November 8, 2013].

Solano, R. et al., 2010. MODIS Vegetation Index User's Guide (MOD13 Series). , 2010(May). Available at: http://vip.arizona.edu.

The University of Arizona, Vegetation Index & Phenology Lab: Nasa MODIS Project. The University of Arizona. Available at: http://vip.arizona.edu/MODIS_Project.php [Accessed January 15, 2015].

United Nations, 2014. World Urbanization Prospects The 2014 Revision, New York.