SPOT Imagery Observation on Mangrove Changes Using NDVI Density Analysis: The Case of Sepang Besar River, Malaysia

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Mangrove forests are confined by river basins and play a role as a hotspot of biodiversity while acting to prevent erosion in the river-coastal system. However, mangroves are changing rapidly at present, driven by urbanization and land use land cover transformation. Similar to other types of vegetation, the mangrove has a unique spectral characteristic that can be distinguished by remote sensing technology. Vegetation indices has been utilized for mangrove change detection and SPOT imagery provide the right spectral and spatial resolution in achieving it. The present study aimed to examine the changes of vegetation index density classes of primary mangrove areas between the year 2009 and 2019 in Sungai Sepang Besar, Sepang Malaysia. The process includes image acquisition, accuracy assessment, ground truthing, and NDVI density analysis. The results show changes in density, types and total areas of mangroves that relate to rapid urbanization and substantial land use transformation of the surrounding areas for the past 25 years.

Keywords: land use, land cover, mangrove changes, normalized difference, vegetation indices, SPOT imagery

Introduction

Vegetation indices extraction is a process of extracting spectral characteristics of remote sensing imagery to quantify vegetation biomass for each pixel in the remote sensing method. Vegetation indices are essential to measure environmental change, particularly for application in biodiversity conservation, forestry, agriculture, urban green infrastructures and other related disciplines (Xue and Sue 2017). Remote sensing has the advantages of high spatial and multi-spectral resolutions, which makes it possible to extract ranges of vegetation. The multi-temporal characteristics of remote sensing also provide consistent and comparable information in addition to lengthy observation.

Vegetation indices have been widely implemented in the measurement of the extent of urban growth to environmental change (Helbich 2019; Lu et al. 2019). Specifically, vegetation indices applied to environmental changes provide not only an objective basis, but also vegetation changes, i.e. between vegetation land cover, such as primary mangrove to secondary mangrove, shrubs or other type of vegetation.

Basic vegetation indices extraction was introduced by Jordan (1969), termed Ratio Vegetation Index,(RVI), which applies a basic principle of red and near-infrared wavelength absorbed by leaves. The algorithm of RVI is:

$$RVI = {}^{R}/_{NIR}$$

where R and NIR are red and near infrared wavelength consecutively. However, the most widely used vegetation extraction is the Normalized Differences Vegetation Index (NDVI) (Xue and Sue 2017; Zaitunah et al. 2018; Jia et al. 2019), which has been applied in this study. NDVI has a higher sensitivity in application to to plant life than other vegetation indices. The NDVI quantify vegetation index utilizing red and near infrared wavelengths is observed by SPOT. The algorithm of NDVI is:

$$NDVI = {}^{NIR-R}/_{NIR+R}$$

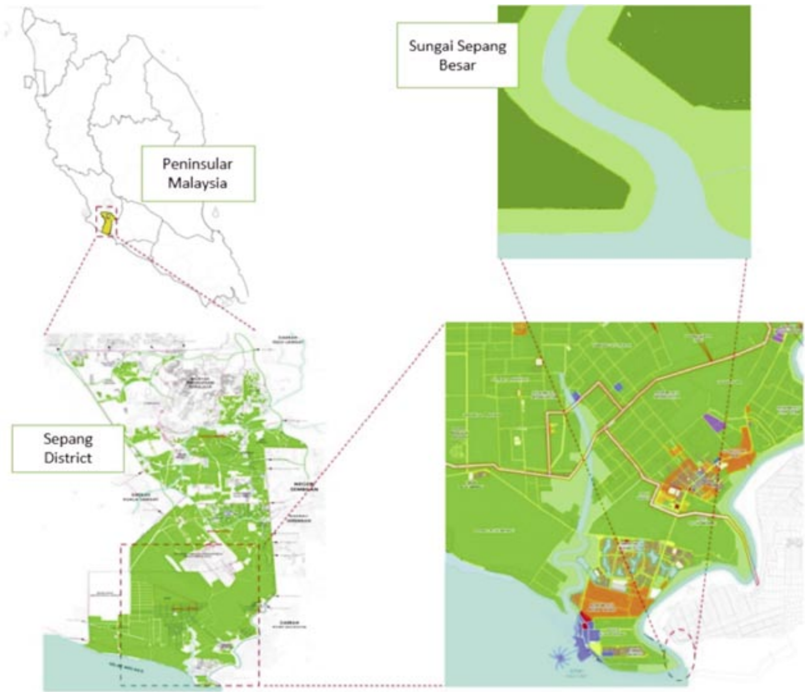
The range of NDVI values is between 0 and 1, representing a sensitive response to green vegetation even for low vegetation covered areas (Xue and Sue 2017). Previous research often used NDVI in global and regional vegetation evaluation (De Keersmaecker et al. 2017; Liu et al. 2017). This index is often used in research related to regional studies because of the ability to perform canopy structure and photosynthesis analysis (Zou and Mottus 2017; La Rue et al. 2018). The present study aimed to examine the changes in density classes and changes of Class II land cover of primary mangrove between the years 2009 and 2019 in Sungai Sepang, Selangor, Malaysia.

Study Area

The study area is at the mouth of Sungai Sepang Besar (Sepang Besar River) in Sepang District, Selangor Malaysia, located at 2° 35’ 55”N and

101° 42' 42"E, and eventually flows into the Straits of Malacca. The study area is 12 km south of the Kuala Lumpur International Airport (KLIA) and the river is also a border between the state of Selangor and Negeri Sembilan. The study area enjoys a tropical climate year around with moderately humid atmosphere, temperatures ranging from 27° to 34°. Cloud coverage is moderately high, and November is the wettest month, although rainfall is highly occasional. Sepang District grew in development swiftly and significantly especially from 1995 to 2015, largely because it surrounds Malaysia's administrative capital of Putrajaya (Yasin et al. 2019). Therefore, an extension of urban growth has been identified that is affecting the ecosystems of Sungai Sepang Besar.

FIGURE 1
Sungai Sepang Besarin Sepang in Peninsular Malaysia



Sepang District has relatively small-sized reserve forests and mangrove areas, with mangrove forests of approximately 546.7 hectares, located along the rivers Sungai Sepang Kecil and Sungai Sepang Besar. These mangrove areas are formed by Rhizophora apiculate, also known by its local name bakauminyak, Sonneratia caseolaris or mangrove apple, and also designated by the local name berembang and loop-root mangrove or bakaukurap in Malay. All of these mangroves grow in salty and saline water in the tidal or coastal area. It possesses biodiversity components of the mangrove ecosystem such as fish, crustaceans and shrimps. The mangrove areas are protected as a Level 1 Environmentally Sensitive Area (ESA) under the Sepang Local Plan 2025 (Sepang 2017).

Data Sets and Accuracy Assessment

This study measures the environmental change of mangrove areas in Sungai Sepang Besar, Sepang District. The primary data are consist of SPOT 5 and SPOT 7 remote sensing imagery as shown in Table 1. SPOT 5 has 10-meter spatial resolution while SPOT 7 has 6-meter spatial resolution. A slightly different path/row was present for the three SPOT 5 imagings but all covered the study area.

TABLE 1
Primary Data

Sensors	Month/ day	Year	Spatial resolution	Path/ row	Band combination
SPOT 5	07/06	2009	10m	269/344	1,2,3,4
	09/12	2012		270/344	
	08/02	2015		270/344	
SPOT 7	26/03	2019	6m	311/212	

Using SPOT imagery dated 2009, 2012, 2015 and 2019, a Supervised Classification was performed in a region of interest of approximately 160 hectares. The region of interest in the study area refers to mangrove forests located along Sungai Sepang Besar. From the classified images, the accuracy assessment was performed for SPOT 5 images in 2009, 2012 and 2015. Kappa coefficients are used to measure the accuracy of classification, which test the confusion matrix of element based on the minimum requirement (Foody 2020). The kappa coefficient is calculated using the equation below:

$$K = \frac{P(A) - P(E)}{1 - P(E)}$$

where, P(A) is the total of k raters that agree, and P(E) is the total of k raters expected to agree by chance (Vanbelle 2017).

User's accuracy is the probability that the pixel on image represents as a class on the ground, while producer's accuracy is the probability that the pixel is correctly classified. This determined whether the classification is fit for further analysis.

TABLE 2
Accuracy assessment of classified image 2009

Class category	Parameters					
	Sensitivity	Specificity	Commission error	Omission error	User's accuracy	Producer's accuracy
High	0.7783	0.7587	0.2413	0.2413	0.742	0.778
Medium	0.7323	0.7734	0.2266	0.2266	0.754	0.732
Low	0.3668	0.7435	0.2565	0.2565	0.738	0.367
Non-vegetation	0.7475	0.7332	0.2668	0.2668	0.801	0.748

TABLE 3
Accuracy assessment of classified image 2012

Class category	Parameters					
	Sensitivity	Specificity	Commission error	Omission error	User's accuracy	Producer's accuracy
High	0.6965	0.6577	0.3423	0.3423	0.677	0.697
Medium	0.7198	0.6929	0.3071	0.3071	0.708	0.720
Low	0.4545	0.7826	0.2174	0.2174	0.656	0.455
Non-vegetation	0.6549	0.7393	0.2607	0.2607	0.692	0.655

TABLE 4
Accuracy assessment of classified image 2015

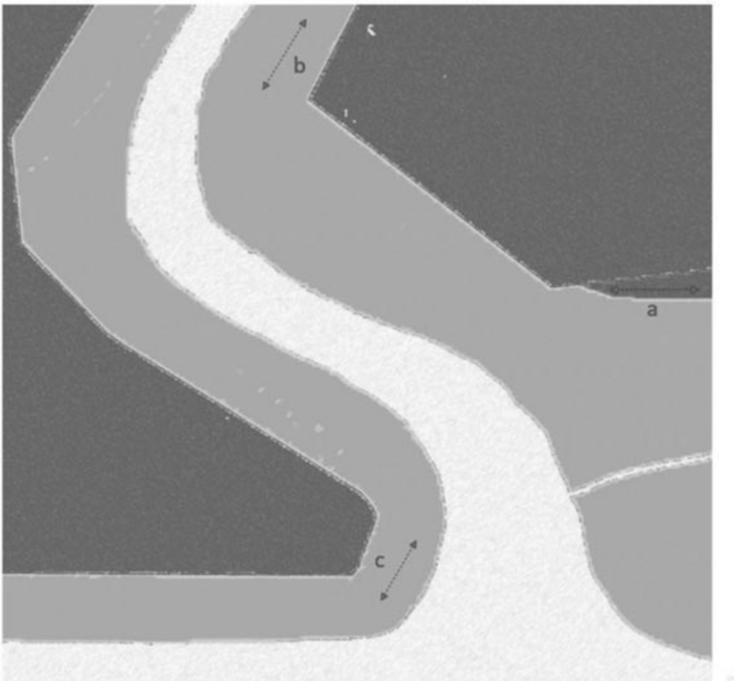
Class category	Parameters					
	Sensitivity	Specificity	Commission error	Omission error	User's accuracy	Producer's accuracy
High	0.7102	0.8117	0.1883	0.1883	0.756	0.710
Medium	0.7335	0.7555	0.2445	0.2445	0.749	0.734
Low	0.5446	0.699	0.301	0.301	0.618	0.545
Non-vegetation	0.7075	0.7241	0.2759	0.2759	0.717	0.708

Tables 2-4 show the high level of accuracy for user's and producer's accuracy for all class categories except low density vegetation. The results obtained showed the overall accuracy ranging from between 77.68 and 81.94 and the kappa coefficient ranging between 0.75 and 0.79, which met the level of agreement and rated as substantial. Thus, the classified images were found to be fit for further analysis.

Ground Truthing

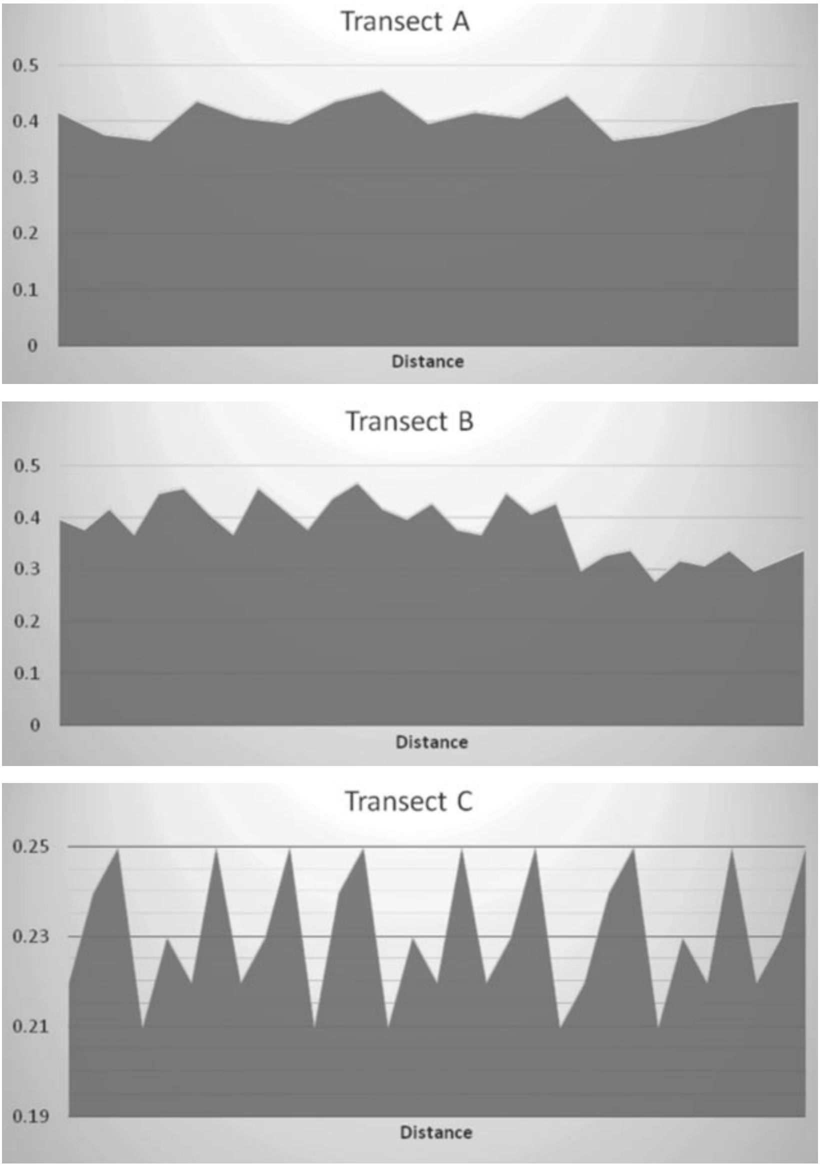
Ground truthing and transect profiling were conducted to measure vegetation ratio in the density classes. Three 30m transects were chosen to capture land cover variation in density classes (Figure 2). Every type of vegetation captured by a unique spectral along the transects was recorded, following the methods in environmental planning. Basically, land cover variation observed in the study area were primary mangrove, mixed mangrove and second-rate mangrove. The primary mangrove consists of Rhizophora apiculate, locally known as bakauminyak, thought to be the predominant species in Sungai Sepang Besar prior to 2009. The mixed mangroves consist of a ratio of bakauminyak and bakaukurap.The second-rate mangrove is the damaged or defective shrub, located mostly in the river mouth of the study area.

FIGURE2
Site transects in site measurement



Transect profile A showed single range high density classes, considered to be primary mangrove – predominantly bakauminyak, while transect profile B has two-range high- density and medium-density classes, deemed to be mixed mangrove, bakauminyak and bakaukurap. Transect profile C showed single range low-density classes, considered to be damaged mangrove shrub.

FIGURE 3
Transect profiles A, B and C with respect to wavelength



Results and Discussions

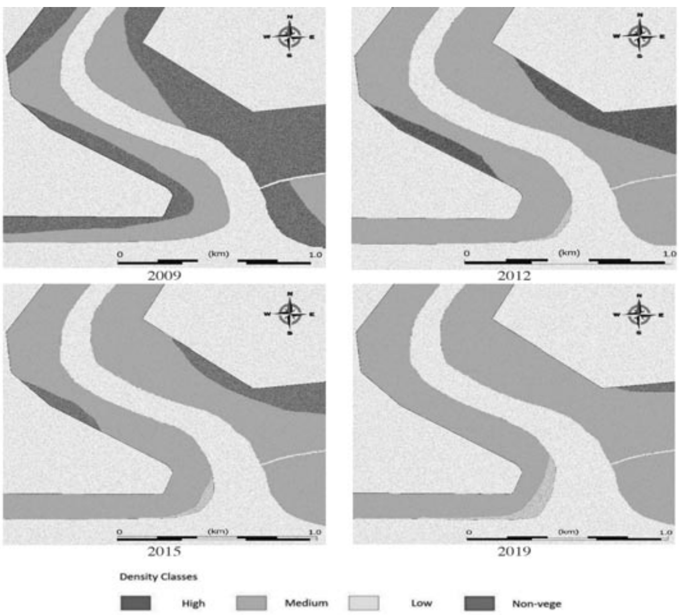
The NDVI was performed for all images and the result of NDVI density classes is presented in Table 5. The density classes are divided into high density, medium density and low-density classes.

TABLE 5
Changes of NDVI density classes between 2009 and 2019

Density classes	2009		2012		2015		2019	
	Ha	%	Ha	%	Ha	%	Ha	%
High	87.47	54.5	19.18	12	15.71	9.9	5.04	3.2
Medium	72.87	45.4	136.95	85.7	137.59	86.7	143.55	91.2
Low	0.16	0.1	3.68	2.3	5.40	3.4	8.81	5.6
Total	160.5	100.0	159.8	100.0	158.7	100.0	157.4	100

The NDVI analysis showed that Sungai Sepang Besar in 2009 was represented by 54.5% high-density classes and 45.4% medium density classes of the total area. In 2012, high- density classes decreased to 12.0%, while medium-density classes increased radically to 85.7%, and low-density classes represented 2.3%. There were slight changes in 2012: high-density classes decreased to 9.9%, medium-density classes increased to 86.7% and low-density classes increased to 3.4%. The trend continued in 2019, where high-density classes decreased to 3.2%, while medium-density classes increased to 91.2% and low-density classes increased to 5.6%. The results also showed that the total mangroves areas were steadily decreasing in area from 160.5 hectares in 2009 to 157.4 hectares in 2019. The NDVI images are presented in Figure 4.

FIGURE 4
NDVI density classes of Sungai Sepang Besar 2009-2019

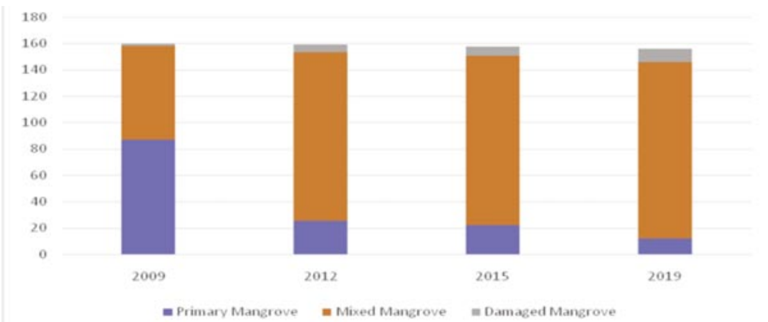


Based on ground truthing or transect profiling, the changes of mangrove density classes are shown in Table 6. In 2009, primary mangrove was the predominant vegetation with 86.56 ha or 54.3%, followed by mixed mangrove 71.34 ha or 44.7% and damaged mangrove 1.5 ha or 0.99%. In 2012, primary mangrove drastically decreased to 25.07 ha or 15.8%, while mixed mangrove increased to 128.26 ha or 81.7% and damaged mangrove increased to 5.69 ha or 4.5%. In 2015, primary mangrove continued to decrease to 21.83 ha or 7.7% while damaged mangrove increased to 7.07 ha or 6.4%, but mixed mangrove did not show much change. In 2019, primary mangrove again had decreased to 12.04 ha or 7.7%, while mixed mangrove increased to 133.79 ha or 85.9% and damaged mangrove increased to 9.9 ha or 6.4%. To conclude, in 10 years, primary mangrove heavily decreased in size and density, while mixed mangrove and damaged mangrove steadily increased.

TABLE 6
Changes of mangrove density class 2009-2019

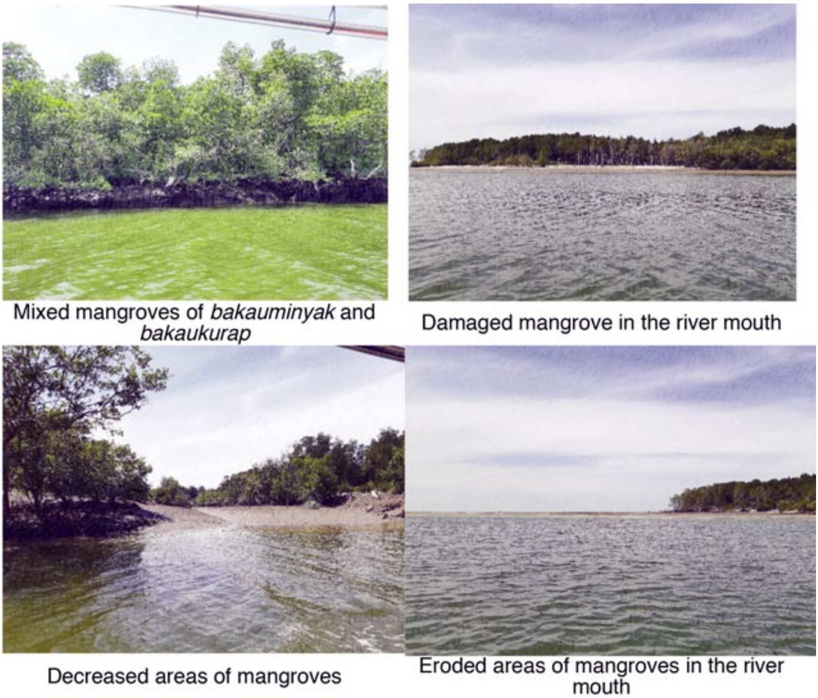
Density	Land cover	2009	2012	2015	2019
High	Primary mangrove	82.92	18.18	14.89	4.78
	Mixed mangrove	3.64	0.96	0.79	0.25
	Damaged mangrove	0.00	0.02	0.02	0.01
	Unknown	0.16	0.02	0.02	0.01
Medium	Primary mangrove	3.64	6.85	6.88	7.18
	Mixed mangrove	67.70	127.23	127.82	133.36
	Damaged mangrove	1.46	2.74	2.75	2.87
	Unknown	0.07	0.14	0.14	0.14
Low	Primary mangrove	0.00	0.04	0.05	0.09
	Mixed mangrove	0.00	0.07	0.11	0.18
	Damaged mangrove	0.13	2.93	4.30	7.02
	Unknown	0.03	0.64	0.93	1.52
Σ		160.50	159.80	158.70	157.40

FIGURE 5
Mangrove changes 2009-2019



Sepang District has been experiencing tremendously rapid urbanization and development over the past two decades (Yasin et al. 2019). Rapid urbanization has transformed land use and land cover of the district from predominantly forest and vegetation areas into urban built-up areas. This urbanization is associated with changes of impervious surface which alter the natural amount of water percolating in the ground, resulting in a decrease in quality and increase in volume of surface runoff water. The use of SPOT imagery and NDVI density analysis provides the precise accurate solution for measuring the extent of urbanization impact on environmental changes, particularly mangrove changes in the study area.

FIGURE 6
Photos of mangroves in Sungai Sepang Besar



Conclusion

The global environmental changes, notwithstanding their dynamism, can be consistently monitored, and remote sensing with vegetation index analysis provides the suitable tools in achieving this aim. The present study relates the ongoing environmental changes, particularly in mangrove areas, to the effects of rapid urbanization and development.

The quality and quantity of surface runoff water derived from the exceptional increase of impervious surface has had a considerable impact on mangrove ecosystems. A distinct change in mangrove forest was observed, reflecting a transition of primary mangroves into mixed mangrove and second-rate mangrove. Another noticeable change was in the river mouth of Sungai Sepang Besar, where decreased and eroded areas of mangroves appeared. The transformation of land use and land cover in Sepang District have changed the river characteristics, and as a result have led to a significant change in mangroves. Thus, rapid urbanization has lessened the quality of water that acts as an essential function of the river, which can alter the well-being of natural ecologies.

References

De-Keersmaecker, W., Lhermitte, S., Hill, M. J., Tits, L., Coppin, P., and Somers, B. 2017. Assessment of regional vegetation response to climate anomalies: A case study for Australia using GIMMS NDVI Time Series between 1982 and 2006. Remote Sensing 9(1):34. https://doi.org/10.3390/rs9010034

Foody, G. M. 2020. Explaining the unsuitability of the kappa coefficient in the assessment and comparison of the accuracy of thematic maps obtained by image classification. Remote Sensing of Environment 239. 15 March, 111630

Helbich, M. 2019. Spatiotemporal contextual uncertainties in Green Space Exposure Measures: Exploring a time series of the Normalized Difference Vegetation Indices. International Journal of Environmental Research and Public Health, 16(852).

Jia, M., Wang, Z., Wang, C., Mao, D., and Zhang, Y. 2019. A new vegetation index to detect periodically submerged mangrove forest using Single-Tide Sentinel-2 imagery. Remote Sensing 11(17).

Jordan, C. F. 1969. Derivation of leaf-area index from quality of light on the forest floor. Ecology 50(4):663-666.

LaRue, E. A., Atkins, J. W., Dahlin, K., Fahey, R., Fei, S., Gough, C., and S.Hardiman, B. 2018. Linking Landsat to terrestrial LiDAR: Vegetation metrics of forest greenness are correlated with canopy structural complexity International. Journal of Applied Earth Observation and Geoinformation 73:420-427.

Liu, R., Shang, R., Liu, Y., and Lu, X. 2017. Global evaluation of gap-filling approaches for seasonal NDVI with considering vegetation growth trajectory, protection of key point, noise resistance and curve stability. Remote Sensing of Environment, 189, 164-179.

Lu, L., Weng, Q., Guo, H., Feng, S., and Li, Q. 2019. Assessment of urban environmental change using multi-source remote sensing time series (2000-2016): A comparative analysis in selected megacities in Eurasia. Science of The Total Environment 684:567-577.

Sepang Municipal Council. 2017. Sepang Local Plan 2025 (Rancangan Tempatan Sepang 2025). Sepang.

Vanbelle, S. 2017. A new interpretation of the weighted kappa coefficients. Psychometrika 81:399-410.

Xue, J., and Su, B. 2017. Significant remote sensing vegetation indices: A review of developments and applications. Journal of Sensors Volume 2017 |Article ID 1353691 | https://doi.org/10.1155/2017/1353691

Yasin, M. Y., Yusoff, M. M., and Noor, N. M. 2019. Urban sprawl assessment using time series LULC and NDVI variation: a case study of Sepang Malaysia. Applied Ecology and Environmental Research 17(3). DOI: 10.15666/aeer/1703_55835602

Zaitunah, A., Samsuri, Ahmada, A. G., and Safitri, R. A. 2018. Normalized difference vegetation index (NDVI) analysis for land cover types using Landsat 8 OLI in Besitang Watershed, Indonesia. IOP Conf. Series: Earth and Environmental Science, 126. IOP Conf. Ser.: Earth Environ. Sci. 126 012112

Zou, X., and Mõttus, M. 2017. Sensitivity of common vegetation indices to the canopy structure of field crops. Remote Sens. 2017, 9, 994; doi:10.3390/rs9100994