PLANNING MALAYSIA:
Journal of the Malaysian Institute of Planners
VOLUME 19 ISSUE 2 (2021), Page 108 – 120

VEGETATION EXTRACTION WITH PIXEL BASED CLASSIFICATION APPROACH IN URBAN PARK AREA

Haslina Hashim[1], Zulkiflee Abd Latif[2], Nor Aizam Adnan[3], Izrahayu Che Hashim[4] and Nurul Fadzila Zahari[5]

[1,4,5] Department of Built Environment Studies and Technology, Faculty of Architecture, Planning and Surveying
UNIVERSITI TEKNOLOGI MARA, PERAK BRANCH, MALAYSIA
[2,3] Faculty of Architecture, Planning & Surveying
UNIVERSITI TEKNOLOGI MARA, MALAYSIA

Abstract

Information on urban vegetation and land use is critical for sustainable environmental management in cities. In general, urban vegetation is important for urban planning because it helps to maintain a balance between the natural environment and the built-up region. The assessment of the composition and configuration of the vegetation is important to highlight the urban ecosystem. Thus, obtaining information about urban vegetation is critical for developing a sustainable urban development strategy. Remote sensing is increasingly being used to generate such data for mapping and monitoring changes in urban vegetation. The aim of this study is to identify and classify vegetation using the high-resolution Pleiades satellite image in urban park areas using pixel-based image analysis. Pixel based method was applied and support vector machine algorithm was used for classification of urban vegetation. Comparison of accuracy was made from the error matrices, overall accuracy and kappa coefficient for vegetation and non-vegetation classes. The overall accuracy for the classification approach was 98.98% and a kappa value of 0.97. The result demonstrates the ability of high-resolution imagery to accurately extract urban vegetation despite the complex surface of the urban area. The findings can be used to support other research and applications related to urban green space monitoring, conservation, and future urban vegetation planning.

***Keywords**:* Remote Sensing, Urban Vegetation, High Resolution, Pixel-Based Classification and Support Vector Machine.

[1] Lecturer at Universiti Teknologi MARA Perak Branch. Email: haslinah8118@gmail.com

INTRODUCTION

In general, urban vegetation provides critical ecological services to support sustainable development policies, environmental conservation, and the urban planning process s (Lehman et al., 2014; Wolch et al., 2014; Niemela, 2014). However, mapping and monitoring urban vegetation has emerged as a major concern for urban planners in terms of future development. (Puissant & Roger, 2014; Wong et al., 2017). Urban vegetation is important for improving air, water, and land quality, as well as absorbing and mitigating carbon dioxide and other pollutants, lowering urban temperatures, and reducing storm water runoff (Pu, 2009; Pu et al., 2006; Weng et al., 2004). Urban vegetation is substantially different from natural vegetation because of extensive human impact on their ecosystems (Rosina & Kopecke, 2016). Mapping and monitoring urban vegetation are critical tasks due to their functions such as air management, contribution to human well-being, and increasing the value of real estate in urban areas (Weber & Hirsch, 1992). Urban vegetation, such as urban trees, is an important tool for urban preservation because it serves a variety of social and environmental functions (Hamzah et al., 2018). According to Rosli et al., (2020), green spaces promote physical activity by providing free and easily accessible locations for active pastimes. Therefore, precise data on the state and structural change of these ecosystems is critical for formulating sustainable development strategies and enhancing urban settings (Song, 2005; Yang et al., 2003). The urban vegetation inventory system is created at the local level and is usually created through traditional methods such as field surveys. This information is only available to local coverage and is restricted to the public domain (Puissant & Rougier, 2014). As ecosystem services are important to understand, researchers are becoming more aware of the role of urban vegetation in sustainable urban ecosystems and the environment (Hashim et al., 2019). Furthermore, there is a need for proper planning in the urban vegetation monitoring program. The urban vegetation monitoring program is a management process that determines the performance status of trees based on an inventory of the number of trees, their condition, structure, and other quantitative or qualitative characteristics (Hamzah et.al., 2020). With the advancement of high-tech remote sensing, this technique can be used as a tool for integrated spatial planning in order to address urban challenges (Gasparovic & Dobrinic, 2020).

Therefore, the mapping and monitoring of this urban vegetation is a major issue for planners towards sustainable development of an urban area. In this context, the objective of this work is to identify and classify urban vegetation from a very high resolution (VHR) optical image using conventional pixel-based classification approaches. This research focused on the extraction of vegetation and non-vegetation features in urban park areas. The methodology is developed, and its performance is evaluated on a dataset of the National Monument Park, Kuala Lumpur, and its surrounding area. This approach will provide relevant information to support future conservation planning decision makers and researchers for urban green areas and urban vegetation areas. The structure of this research paper is divided into three sections, the introduction and literature review, the second section clarifies the methodology, and the third section presents the findings of this study.

LITERATURE REVIEW

Urban Park is a place with a natural environment located in the city area. This area contains various green vegetation species from low vegetation, medium and high vegetation such as grass, scrub and trees respectively. This area provides a place for various activities such as recreation, meditation, tourist attractions and a place to experience the beauty of nature (Razak et al., 2016). This space is ideal for a variety of activities such as recreation, meditation, tourist attractions, and experiencing nature's beauty (Razak et al., 2016). The quality of urban parks has been identified as being relevant to community life satisfaction, whereas health quality is correlated (Nurul Syakila et al., 2018). Therefore, the role of various types of urban green spaces (parks) in promoting active lifestyles has been studied and proven in several developed countries (Rosli et al., 2020). However, because the urban landscape is always changing, mapping and monitoring vegetation and green space is extremely challenging.

Remote sensing technology has shown to be a cost-effective method for classification and mapping for future planning. Remotely sensed data and imagery nowadays able to satisfy the mapping and monitoring requirement (Erasu, 2017). Furthermore, this high spatial resolution data has been used in multi-level applications worldwide to expand undeveloped areas towards developing nations (Maktav et al., 2005). Furthermore, the advancement of remote sensing data has enabled this valuable information to benefit a variety of users, including urban planners and authorities (Latif et al., 2012; Ibrahim et al., 2015). In recent years, advances in remote sensing technology have provided a useful solution for the monitoring and mapping of urban vegetation (Tooke et al., 2009; Tigges et al., 2013; Pu & Landry, 2012; Immitzer et al., 2012; Hashim et al., 2019). Traditional vegetation mapping methods rely on the interpretation of aerial photographs and field verification, this method is costly, time-consuming, and labor-intensive (Kamagata et al., 2006). However, the availability of very high-resolution (VHR) remote sensing imagery such as IKONOS, Quickbird, Worldview-3, and Pleiades, as well as advanced classification algorithms, allows for the extraction of detailed information on urban vegetation cover (Zylshal et al., 2016; Hashim et al., 2019). Furthermore, with the availability of very high-resolution imagery and a digital classification approach, urban vegetation monitoring and mapping can be done effectively. Some research has been conducted to classify land cover, and the results have been used to analyze the urban green area (Simarmata, 2012; Trisakti, 2016; Zylshal et al., 2016).

Recently, medium- and high-resolution remote sensing imaging has been used to monitor and map vegetation in urban areas (Trisakti, 2017). The remote sensing classification approach, such as automated or semi-automated classification, can eliminate subjectivity while also providing a reproducible procedure (Belgiu et al., 2014). Therefore, this study focuses on pixel-based classification of urban vegetation using Pleiades high-resolution remote sensing data.

The classification method was the most essential aspect of the processing of remotely sensed data (Roy & Giriraj, 2008). Traditional classification methods, such as pixel-based with maximum likelihood approaches, have been widely used in mapping of land use and land cover, and are based on multivariate probability density functions of classes (Lillesand et al., 2008; Hashim et al., 2019). However, advanced classification algorithms, such as support vector machine (SVM), have recently been developed to improve classification accuracy (Deilmai et al., 2014). SVM is a supervised classification with non-parametric learning algorithm that does not make assumptions about the frequency distribution of the data (Belgiu & Drăguţ, 2016; Mountrakis et al., 2011). SVM is a robust, accurate and effective classifier for extracting land cover information from multispectral imagery (Gao & Liu, 2014; Nurul Iman Saiful Bahari et al., 2014). Some research has shown that SVM algorithms are better at classifying than conventional methods (Szuster et al., 2011; Yu et al., 2012). For example, research conducted by Zylshal et al. (2016) and Hashim et al. (2019) that extract urban green space from Pléiades images using SVM classifier produce an acceptable result for the overall accuracy. Moreover, research conducted by Ouerghemmi et al. (2018) has proven that high resolution imagery is able to identify urban vegetation species with acceptable accuracy result and coherent distribution on the visual inspection. According to prior study, using a high-resolution data source and an advanced classification methodology will improve the accuracy of urban vegetation mapping in the future. Therefore, to provide accurate information for this natural resource, it is crucial to explore classification and an algorithm to enhance the result of urban vegetation extraction and classification. The finding of this research study can assist state authorities establish an effective urban vegetation information system for future conservation planning.

RESEARCH METHOD

Scope of the Study

This study focuses on the extraction of the vegetation and non-vegetation features in urban park, Tugu Park in Kuala Lumpur, and its surrounding area. Two features of the vegetation and non-vegetation area will be extracted and analyzed using high-resolution Pleiades satellite imagery. ENVI software will be used to process high-resolution satellite images, and a traditional pixel-based classification approach will be used for extraction and classification. The statistical error matrices, overall accuracy, and kappa coefficient will be used to assess the accuracy of the classification of vegetation and non-vegetation areas. The highest overall accuracy indicates that urban vegetation can be successfully identified and classified.

Case Study
The selected study area is located in National Monument Park, Kuala Lumpur, Malaysia. The study area covers the coordinates of 3º 8’ 51” N, 101º 41’ 36” E. The National Monument Park is located to the north of Taman Botani Perdana, Padang Merbok in the south-east and Bank Negara’s Lanai Kijang to the east of the site. The site is contiguous with Taman Botani Perdana separated only by Parliament road and can be seen as an expansion of that green spaces.

Figure 1. Pleiades imagery of National Monument Park, Kuala Lumpur
Source: Google earth

DATA COLLECTION

For this research study, secondary data was collected from two government agencies. The first one was tree inventory data from the Landscape department, City Hall Kuala Lumpur and the second primary data was the satellite imagery provided by Malaysia Agency of Remote Sensing ARSM). The specific satellite images used were Pleiades 1A Orthorectified Pansharpened for year of 2017 with less than 10% cloud cover. The detail of data used is shown in Table 1. Other supporting data include the land use map that has been provided by the Town and Regional Planning department, City Hall, Kuala Lumpur for validation of the classification stage.

Table 1: Pleiades 1A satellite imagery data specification

Data	Date of Acquisition	Processing Level	Spectral Resolution	Spatial Resolution
Pleiades 1 A	3 Februari 2017	Orthorectified	Blue: 480 - 830 nm Green: 490 - 610 nm Red: 600 - 720 nm Near Infrared: 750 - 950 nm Panchromatic: 480 - 830 nm	2 m 0.5 m

Source: http://www.satimagigcorp.com/satellite-ssensors/pleiades-1/

Image Pre-processing and Analysis

The methodology flowchart is shown in Figure 2. The overall data processing can be divided into three main processes, as follows: 1) The pre-processing of the satellite images. 2) The classification stage, and 3) accessing the accuracy for classification method. Pleiades imagery is obtained as standard products that have been geometrically and radiometrically corrected by data providers, allowing it to be used directly and proceed to the second stage, which is the classification process. In the classification stage, urban vegetation and non-vegetation features were accurately identified and classified using satellite images with high resolution. A uniform supervised classification was applied to the images. All images were classified by creating accurate polygons as training areas for introducing ideal classes for each image separately. To create a closer correspondence between the maps that were produced, the classification was done by only considering two main classes: vegetation and non-vegetation area. Pixel based Support Vector Machine (SVM) algorithm were used for this classification process. The description of the main classes is presented in Table 2. Land use map was used to validate the classification result. The accuracy of the classification result was tested using a confusion matrix consisting of overall accuracy, user accuracy, producer accuracy and kappa coefficient. The final output from this study was the urban vegetation extraction with high resolution satellite imagery.

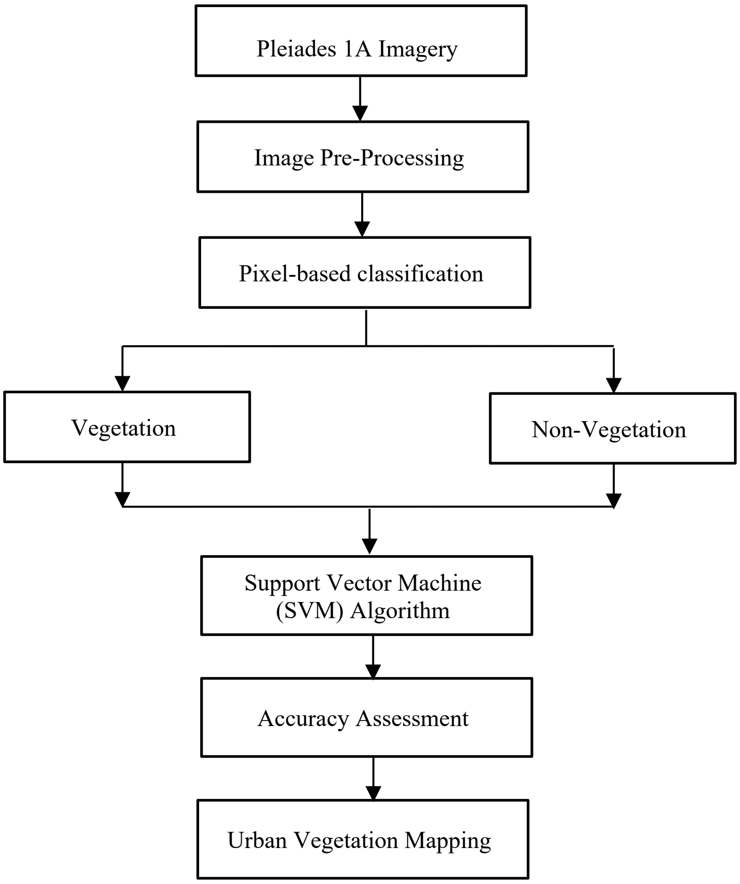

Figure 2. The methodology flow chart of urban vegetation mapping

Table 2: Description of land use/cover classes

Land use classes	Description
Vegetation	Shrub lands and semi natural vegetation, gardens, inner city tree areas, grass land and vegetable land, trees, coniferous forest and mixed forest
Non-Vegetation	Infrastructure, park and playground, building, car park and National Monument

RESULT AND DISCUSSION

Figure 3 shows the result of urban vegetation extraction and classification. The land use land cover was classified into vegetation and non-vegetation area. The comparison of both techniques was based on a visual analysis of the respective land use maps outputs and on the evaluation of the corresponding accuracy assessment measures (overall, producer's and user's accuracies, kappa coefficient). Comparison of accuracy was made from the error matrices, overall accuracy, and kappa coefficient. The overall accuracy for the classification approach was 98.98% and a kappa value of 0.97. The findings show that a pixel-based classification system can distinguish between vegetation and non-vegetation in an urban environment. Table 3 describes in detail the accuracy assessment for urban vegetation mapping with support vector machine (SVM) classification approach. From Table 3, the extraction result of vegetation features was 97.79% and 100% for producer and user accuracy, respectively. While for non-vegetation the accuracy for producer and user was 100% and 98.14% respectively. The results demonstrate the ability of very high-resolution images to accurately extract urban vegetation despite the complex surface of an urban park area. Therefore, the results demonstrate the ability to extrait and classify urban vegetation moderately in the municipal park area with pixel-based image analysis with support vector machine (SVM).

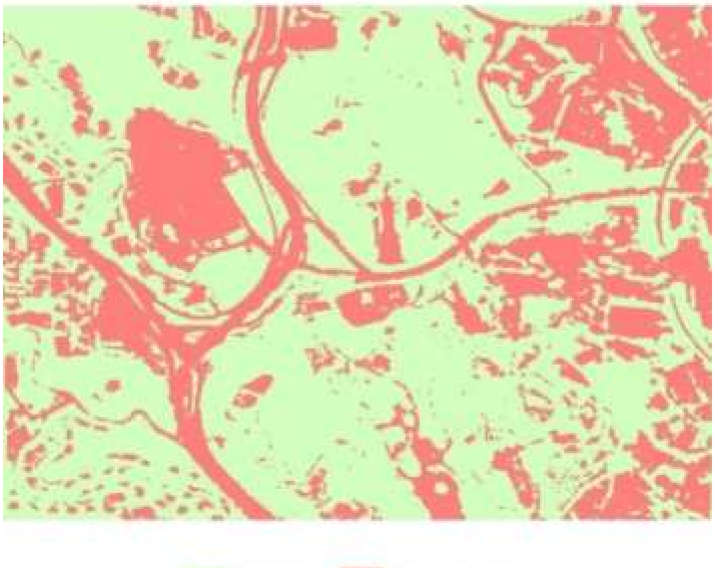

Figure 3. Urban vegetation classification with SVM classification algorithm

Table 3: Accuracy assessment result for urban vegetation classification

Year	2017	
Land Use/Land Cover	Producer's Accuracy (%)	User's Accuracy (%)
Non-Vegetation	100	98.14
Vegetation	97.79	100
Overall Accuracy	98.98%	
Kappa Coefficient	0.9795	

CONCLUSION

In conclusion, the results of this study show that the pixel-based image analysis approach with the use of the support vector machine (SVM) classification algorithm can provide accurate results and be useful for the generation of vegetation maps, with a kappa coefficient of 0.9795 and overall accuracy of vegetation and non-vegetation extraction of 98.98 percent. This shows that the pixel-based image analysis approach with the use of the SVM classification algorithm can provide accurate results and be useful for the generation of vegetation maps. This data will be useful in future conservation planning for urban green spaces. More importantly, the precise results of this study give policymakers and tree managers with correct data to make future decisions about the conservation of urban tree areas.

In addition, this research has shown that high-resolution Satellite Imaging with a suitable classification algorithm has a great potential for use when generating and updating vegetation data needed to manage urban landscapes appropriately. To properly manage urban vegetation for maintenance purposes, an updated and accurate tree information can be developed to assist the planning application for managing green spaces and vegetation in urban park areas in accordance with the Tree Preservation Order under the Town and Country Planning Act 1976. (Act 172). The systemic information system for urban vegetation and green areas will be able to efficiently manage large quantities of information and can be digitally visualized. The State authorities will benefit from this for future urban planning. With a new advanced classification methodology that combines acceptable high-resolution remote sensing data, classification accuracy can be enhanced even further in the future. To create a novel approach for urban vegetation detail categorization and mapping, more research is required.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to the data providers such as Malaysia Agency of Remote Sensing for high resolution satellite imagery (Pleiades 1A), Town and Regional Planning Department, City Hall Kuala Lumpur for Land use map of Kuala Lumpur (2016). The authors would also like to thank all organisations and individuals who had contributed to this research study.

REFERENCES

Alonzo, M., McFadden, J.P., Nowak, D.J., & Roberts, D.A. (2016). Mapping urban forest structure and function using hyperspectral imagery and LiDAR data. *Urban Forestry & Urban Greening*, *17*, 135-147. https://dx.doi.org/10.1016/j.ufug.2016.04.003

Belgiu, M., & Drăguţ, L. (2016). Random forest in remote sensing: A review of applications and future directions. *ISPRS Journal of Photogrammetry and Remote Sensing, 114(Supplement C)*, *114*, 24–31. https://doi.org/10.1016/j.isprsjprs.2016.01.011

Caccetta, P., Collings, S., Hingee, K., McFarlane, D., & Wu, X., (2011). Fine-scale monitoring of complex environments using remotely sensed aerial, satellite and other spatial data. *International Symposium on Image and data fusion (ISIDF 2011)*. http://hdl.handle.net/102.100.100/103346?index=1

Deilmai, B.R., Ahmad, B., & Zabihi, H. (2014). Comparison of two classification methods (MLC and SVM) to extract land use land cover in Johor, Malaysia. *IOP Conference Series: Earth and Environmental Science 20*. https://doi.org/10.1088/1755-1315/20/1/012052

Erasu, D. (2017). Remote Sensing-based urban land use/land cover change detection and monitoring. *Journal of Remote Sensing & GIS*, *6*(2). https://doi.org/10.4172/2469-4134.1000196

Gasparovic, M., & Dobrinic, D. (2020). Comparative Assessment of Machine Learning Methods for Urban Vegetation Mapping Using Multitemporal Sentinel-1 Imagery. *Remote Sensing, 12(12), 1952. MDPI AG*. Retrieved from http://dx.doi.org/10.3390/rs12121952

Gao, Z., & Liu, X. (2014). Support vector machine and object-oriented classification for urban impervious surface extraction from satellite imagery. *Paper presented at the 2014 The Third International Conference on Agro-Geoinformatics.* https://doi.org/10.1109/Agro-Geoinformatics.2014.6910661

Hashim, H., Abd Latif, Z., and Adnan, N.A (2019). Urban vegetation classification with NDVI threshold value method with very high resolution (VHR) Pleiades imagery, Int. Arch. Photogram. *Remote Sens. Spatial Inf Sci. XLII-4/W16*, 237-240. https://doi.org/10.5194/isprs-archives-XLII-4-W16-237-2019.

Hamzah, H., Othman, N., Mohd Hussain, N. H. (2020). Setting the criteria for urban tree vandalism assessment. *Planning Malaysia Journal of the Malaysian Institute of Planners, 18*(4), 12-32. http://dx.doi.org/10.21837/pm.v18i14.815

Hamzah, H., Othman, N., Mohd Hussain, N. H., & Simis, M. (2018). The criteria of urban trees regarding the issues of tree vandalism. *IOP Conference Series: Earth and Environmental Science*, *203*, 1–6. https://doi.org/10.1088/1755-1315/203/1/012023

Immitzer, M., Atzberger, C., & Koukal, T. (2012). Tree species classification with random forest using very high spatial resolution 8-band World View-2 satellite data. *Remote Sensing*, *4*, 2661-2693. https://doi.org/10.3390/rs4092661

Ibrahim, N., Ujang, U., Desa, G., & Ariffin, A. (2015). Analysing the sustainability of urban development: A review on the potential use of volunteered geographic information. *ISPRS Annal of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. 169-174. https://doi.org/10.5194/isprsannals-II-2-W2-169-2015

JPBD Semenanjung Malaysia. (2011). PPA 06 – Panduan Perlaksanaan Akta 172: Perintah Pemeliharaan Pokok [Guidelines of Act 172: Tree Preservation Order]. 1-24.

Kamagata, N., Hara, K., Mori, M., Akamatsu, Y., Li, Y. & Hoshino, Y. (2006). A new method of vegetation mapping by object-based classification using high resolution satellite data. *Journal of the Japan Society of Photogrammetry and Remote Sensing*, *45*(1), 43-49. https://doi.org/10.4287/jsprs.45.43

Latif, Z.A., Zamri, I. & Omar, H. (2012). Determination of trees species using WorldView-2 data. *IEEE 8th Int. Conf. on Signal Process Application. and Technology (ICSPAT)*, 383–387. https://doi.org/10.1109/CSPA.2012.6194754

Law of Malaysia (2006). Town and Country Planning Act 1976 (Act 172). The Commissioner of Law Revision Malaysia. *Malaysia: Percetakan Nasional Malaysia Bhd*. 1-132. Retrieved from https://www.planmalaysia.gov.my/index.php/en/lihat-akta-172

Lehman, I., Mathey, J. Rößler, S., Bräuer, A., Goldberg, V. (2014). Urban vegetation structure types as a methodological approach for identifying ecosystem services – Application to the analysis of micro-climatic effects. *Ecological Indicators*, *42*, 58 – 72. https://doi.org/10.1016/j.ecolind.2014.02.036

Lillesand, T.M., Kiefer, R.W. & Chipman, J.W. (2008). Remote Sensing and image interpretation 6th *edition (New York: John Wiley & Sons Ltd)*.

Maktav, D., Erbek, F.S., & Jurgen, C. (2005). Remote Sensing of urban areas. *International Journal of Remote Sensing, 26*, 655-659. https://doi.org/10.1080/01431160512331316469

Nichol, J., & Lee, C.M. (2005). Urban vegetation monitoring in Hong Kong sings high resolution multispectral images. *International Journal of Remote Sensing*, *26*, 903. https://doi.org/10.1080/01431160412331291198

Niemela, J. (2014). Ecology of urban green spaces: The way forward in answering major research questions. *Landscape and Urban Planning*, *125*, 298–303. https://doi.org/10.1016/j.landurbplan.2013.07.014

Nurul Iman Saiful, B., Asmala, A., & Burhanuddin Mohd, A. (2014). Application of support vector machine for classification of multispectral data. *IOP Conference Series: Earth and Environmental Science*, *20*(1), 012038. https://doi.org/10.1088/1755-1315/20/1/012038

Nurul Shakila, K. Nurul Faizah, B. & Hazlina, H. (2018). Improving quality of life through recreational behaviour in urban park. *Asian Journal of Quality of Life, 3*(13), 80-88. https://doi.org/10.17576/geo-2021-1701-08

Pu, R.L., & Landry, S. (2012). A comparative analysis of high resolution IKONOS and World View-2 imagery for mapping urban tree species. *Remote Sensing of Environment*, *124*, 516-533. https://doi.org/10.1016/j.rse.2012.06.011

Pu, R., Gong, P., Michishita, R., & Sasagawa, T. (2006). Assessment of multi-resolution and multi-sensor data for urban surface temperature retrieval. *Remote Sensing of Environment*, *104*, 211–225. https://doi.org/10.1016/j.rse.2005.09.022

Pu, R. (2009). Broadleaf species recognition within situ hyperspectral data. *International Journal of Remote Sensing*, *30*(11), 2759–2779. https://doi.org/10.1080/01431160802555820

Razak, M.A.W.A., Othman, N., & Nazir, N.N.M. (2016). Connecting people with nature: Urban park and human well-being. *Procedia-Social and Behavioural Sciences*, *222*, 476-484. https://doi.org/10.1016/j.sbspro.2016.05.138

Rosli, S., Leh, O.L.H., Mohd Adzmi, N.A., & Marzukhi, M.A. (2020). Relationship between quality of urban parks and physical activity: A case study in Changkat public park, Batu Gajah, Perak. *Planning Malaysia Journal of the Malaysian Institute of Planners, 18*(4), 158-172. http://dx.doi.org/10.21837/pm.v18i14.824

Rougier, S., & Puissant, A. (2014). Improvements of urban vegetation segmentation and classification using multi-temporal Pleiades images. *South Eastern European Journal of Earth Observation and Geomatics*, *3*(2). 409-414.

Roy, P., & Giriraj, A. (2008). Land use land cover analysis in Indian context. *Journal of Applied Sciences*, *8*, 1346-1353. https://doi.org/10.3923/jas.2008.1346.1353

Simarmata, M. (2012). Kajian Ketercukupan Ruang Terbuka Hijau Berdasarkan Jumlah Penduduk Kota Pematangsiantar. *Jurnal Akar*, *1*, 91-103

Szuster, B.W., Chen, Q., & Borger, M. (2012). A comparison of classification techniques to support land cover and land use analysis in tropical coastal zones. *Journal of Applied Geography 31*, 525-532. https://doi.org/10.1016/j.apgeog.2010.11.007

Trisakti, B. (2017). Vegetation type classification and vegetation cover percentage estimation in urban green zone using Pleiades imagery. *IOP Conference Series: Earth and Environmental Science 54*(2017) 012003. Doi: 10.1088/1755-1315/54/1/012003. https://doi.org/10.1088/1755-1315/54/1/012003

Tigges, J., Lakes, T., & Hostert, P. (2013). Urban vegetation classification: Benefits of multitemporal RapidEye satellite data. *Remote Sensing of Environment*, *136*, 66-75. https://doi.org/10.1016/j.rse.2013.05.001

Tooke, R.T., Coops, Goodwin, N.R., Voog, J.A. (2009). Extracting urban vegetation characteristics using spectral mixture analysis and tree classification. *Remote Sensing of Environment*, *113*, 398-407.

Ouerghemmi, W., Gadal, S., Mozgeris, G., & Jonikavicius, D. (2018). Urban vegetation mapping by airborne hyperspectral imagery; feasibility and limitations. *2018 9th Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS)*. https://doi.org/10.1109/WHISPERS.2018.8747112

Weber, C. & Hirsch, J. (1992). Some urban measurement from SPOT data: Urban life quality indices. *International Journal of Remote Sensing*, *13*, 3251-3261. https://doi.org/10.1080/01431169208904116

Weng, Q., Lu, D., & Schubring, J. (2004). Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies. *Remote Sensing of Environment*, *89*, 467–483. https://doi.org/10.1016/j.rse.2003.11.005

Wolch, J. R., Byrne, J., Newell, J. P. (2014). Urban green space, public health and environmental justice: The challenge of making cities just green enough. *Landscape and Urban Planning*, *125*, 234–244. https://doi.org/10.1016/j.landurbplan.2014.01.017

Wong, C.H., Mew, A.A., & Perumal, B. (2017). Urban Community Forest, Bukit Persekutuan. *Malaysian Nature Society. Kuala Lumpur, Malaysia*. Retrieved from https://ucfnetworkbukitpersekutuan.files.wordpress.com/2017/11/ucf-booklet.pdf

Yu, L., Porwal, A., Holden, E.J., & Denith, M.C. (2012). Towards automatic lithological classification from remote sensing data using support vector machines. *Journal of Computer & Geosciences,* *45*, 229-239. https://doi.org/10.1016/j.cageo.2011.11.019

Zylshal, Sulma, S., Yulianto, F., Nugroho, J. T., & Sofan, P. (2016). A Support Vector Machine object-based image analysis approach on urban green space extraction using Pleiades-1A imagery. *Modelling Earth Systems Environment* *2*(2). https://doi.org/10.1007/s40808-016-0108-8

Received: 17th May 2021. Accepted: 9th July 2021