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LANDSCAPE PATTERN AND CONNECTIVITY IMPORTANCE OF PROTECTED AREAS IN KUALA LUMPUR CONURBATION FOR SUSTAINABLE URBAN PLANNING

Mohammad Imam Hasan REZA[1,2*], Saiful Arif ABDULLAH[2], Shukor Bin Md. NOR[3], Mohd Hasmadi ISMAIL[4]

[1] Southeast Asia Disaster Prevention Research Initiative (SEADPRI), Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.
[2] Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor Darul Ehsan, Malaysia
[3] School of Environment and Natural Resources, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor Darul Ehsan, Malaysia
[4] Department of Forest Production, Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor Darul Ehsan, Malaysia.

Abstract

*Protected areas in the cities play an important role for nature conservation and sustainable urban planning. In many occasions however development activities and urban planning ignore this ecological aspect. For sustainable urban planning, understanding the landscape pattern and connectivity importance of urban protected areas and its surroundings are important. Therefore, this study examined: **i)** landscape pattern changes of three protected areas - Bukit Sungai Puteh, Bukit Nenas and KL Golf Course and **ii)** their connectivity importance for biodiversity conservation of Kuala Lumpur conurbation. In this study three satellite images (Landsat TM 30 m resolution) of the study areas in 1988, 1996 and 2005 were processed and analyzed using ERDAS Imagine 9.2 and ArcGIS 9.3 to develop land use/land cover maps of the study areas in the three years. Landscape pattern of the maps was analyzed using landscape metrics calculated by Vector Based Landscape Analysis Tools Extension (^{V}LATE) software. Conefor Sensinode 2.2 (CS22) software was used to measure landscape connectivity. Results revealed that over the decades the protected areas experienced highly pressure from anthropogenic activities. Generally, their size is very small and the natural areas within their boundary gradually reduced and fragmented. Analysis also revealed the transformation of natural landscape to the anthropogenic settlements inside all of the three protected areas. This suggests that these protected areas may have lost their capability to support valuable biodiversity if the situation persisted. However, the connectivity analysis showed that some of the large patches of forest outside the protected areas have connectivity importance. Therefore, there is a need for more protected areas in the Kuala Lumpur conurbation to protect valuable biodiversity and also the natural landscapes for sustainable planning of the city.*

Keywords: *Landscape ecology; Ecological integrity; Urban ecosystem; Biodiversity; Protected area; Landscape connectivity*

Introduction

Urban areas are increasing in an unprecedented rate and presently hosting more than half of the global population [1, 2]. This massive urbanization will likely have significant effects on the natural environment and the ecosystem goods and services of the cities [3]. Although, many

* Corresponding author: rezamih@gmail.com

believe that the natural areas in an urban setting possess comparative high species richness than the non-urban areas [4, 5] and thereby is becoming a central concern of urban planning. However, the usual characteristics of cities (e.g., limitation of semi-natural habitats and open space, fragmentation) challenge sustainable urban planning in order to the protection of species and enhancing their facilities (e.g., limiting human encroachment, facilitating functional connectivity). Reducing the semi-natural and open spaces in the urban area may limit habitat space of many species [6].

There is a growing trend of urbanization in the Asia [1] although presently the proportion is 40% which is much lower than the North America (81%), Europe (72%) and Australia (88%). It is expecting that Asia will be rapidly urbanized in the coming decades [7]. However, long-term monitoring of biological resources of protected areas located in the urbanized areas is central to monitoring the ecological integrity and the social value of those areas [8]. Therefore, the methods must be flexible and able to address multiple objectives across broad spatial and temporal scales.

Changes in spatial patterns of land use and land cover both within and around protected areas can greatly affect ecological pattern and processes within those areas [9-11]. In particular, landscape patterns related to disturbance, fragmentation, land cover change, and landscape connectivity have been studied to monitor the ecological integrity in the urban environment [12]. Increasingly, aerial and satellite image data have been using to understand the drivers of changes of natural resources for conservation planning [11, 13].

In this paper, we evaluate the spatial changes due to anthropogenic activities through landscape pattern analysis using remote sensing data of three consecutive decades. We include common landscape size and shape metrics to quantify changes of landscape attributes. Landscape connectivity also measured using a graph theory approach. The objective of the study was to monitor the landscape pattern changes inside and outside the protected areas in an urban setting and also to identify the potential areas which can be included in the protected area network for sustainable urban planning.

Experimental Part

Study area

Kuala Lumpur is located in Peninsular Malaysia, lies on the alluvial plain of the valley of the Klang River. The Klang Velley is also known as the Greater Kuala Lumpur or Kuala Lumpur Conurbation. Located in the center of the State of Selangor, Kuala Lumpur was previously the capital of the state. In 1974, Kuala Lumpur was separated from the state and become the Federal Territory of Malaysian Federal Government. The municipality of the city covers around an area of 243km^2 with an average elevation of 22m asl.

Protected by the Titiwangsa Mountain in the east and Indonesia’s Sumatra Island in the west, Kuala Lumpur has a tropical rainforest climate. Temperature tends to remain constant and thus is warm and sunny along with abundant rainfall. Generally, Kuala Lumpur weather has uniformity throughout the year with day time temperature from 25-28ºC with 80% humidity. Kuala Lumpur is the cultural, financial and economic centre of Malaysia due to its geographic location. It is the most populous city in Malaysia, with a population of 1.6 million in 2010 [14] having a population density of 6,696 inhabitants per sq km. This city is an enclave within the State of Selangor and its urban settlements also increasing around its border towards the State of Selangor (Fig. 1).

Data acquisition and land use/land cover mapping

Landsat TM 30m resolution images of the year 1988, 1996 and 2005 were selected to develop land use/land cover maps of the study area. These satellite images were obtained from the Remote Sensing Agency, Malaysia (ARSM). All images are geo-corrected by the ARSM. These images were then subsequently processed using ERDAS Imagine 9.2 remote sensing software. Supervised classification was carried out using the Maximum Likelihood algorithm (statistically based classifier) technique which is based on Bayesian probability theory (ERDAS Field Guide 1999). Several topographic and land use maps (scale 1:50,000) of the year 1988, 1990, 1996, and 2005 obtained from the Department of Survey and Mapping, Malaysia (JUPEM) and the Department of Agriculture, Malaysia, and field observation were used as the reference in this classification process. Through this classification process, land-use map of the study area of 1988, 1996 and 2005 were produced. There are seven land use/land cover types have been identified as: *i)* built-up area, *ii)* cleared land, *iii)* commercial agriculture, *iv)* forest, *v)* mangrove, *vi)* paddy and other agriculture, and *vii)* water body. An accuracy analysis was performed to evaluate the authentication of the processed images. The overall accuracies were 88.7%, 86.3% and 84.8% for the year 1988, 1996 and 2005, respectively and the Kappa statistics values for each of the three years were more than 0.8. These results indicate that the classification procedure was acceptable and land use classes of the study area were accurate [15].

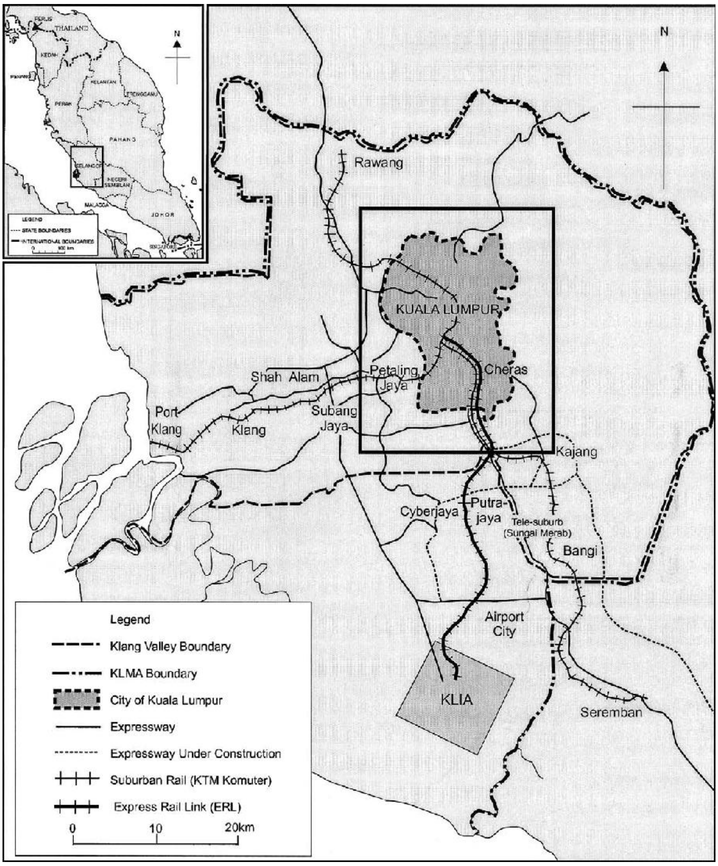

Fig. 1. Kuala Lumpur and its surrounding urban areas

Landscape pattern analysis

The base land use maps developed following the above procedure are the raster data maps. These data maps were then vectorized (shape file) using ArcGIS 9.3. After cross referencing and verified by the literatures, land use maps and topographic maps, the vector data map were used for the landscape pattern analysis. Vector-based Landscape Analysis Tools Extension (v-LATE, http://www.geo.sbg.ac.at/larg/vlate.htm) was used for landscape pattern analysis [16]. Several landscape indexes were chosen and analyzed. For the landscape and class level the following indices were analyzed and calculated: (1) total number of patches of the patch type (NP); (2) class area (sum of the area of all patches of the corresponding patch type); (3) mean patch size; (4) total edge; (5) edge density (amount of edge of patch area per 100 ha of forest assuming a 50m edge effect either side of a patch perimeter); (6) mean shape index (measuring the complexity); (7) mean perimeter area ratio and (8) fractal dimension (also for the measurement of the complexity in shape). Here, number of patch, class area (patch area) and mean patch size were selected for a better interpretability of the fragments since the number of patches alone does not have information about area, distribution or shape of the fragments [17, 18]. Mean shape index [19] and fractal dimension [20-22] are variations of an area to perimeter ratio where 1.0 represents a perfect shape (circle or straight line, Euclidian distance) and larger numbers indicating the increasing the departure from the perfect shapes and increasing shape complexity. Values increasing from 1 to 2 indicating a change of the surface/peripheral configuration from smooth and regular to the irregular and rough surfaces. Generally, it is believed that the natural structure likely to show an irregular fractal peripheral pattern [23-26].

Landscape connectivity analysis

Generally, connectivity analysis is focused on the conservation of key species or habitat which may correspond to a particular land cover type, e.g. forest, or combinations of land cover types [27]. Moreover, without considering the behavior of the wildlife present in the landscape will not provide real information from the analysis. Therefore, the key species dispersal ability has been considered for the threshold of the distance that can be considered as connected. In this study area, medium to small size mammals were considered as the indicator species for wildlife and their movement ability was taken into account for connectivity measurement. Distance threshold selected for this analysis was 200m and 500m since the study area is highly developed and they are the probable suitable distances for wildlife movement [27].

Forest patches have been selected for the landscape connectivity analysis. There are 573 forest patches were delineated from the land use/land cover map of the year 2005. Since the analysis of landscape connectivity was aimed for the identification of the connectivity potential areas for the sustainable urban planning, therefore, LU/LC maps of the years 1988 and 1996 were not considered. Graph-based connectivity metrics were chosen for the analysis as they have been effective in connectivity analysis and prioritizing important patches for conservation [27-31]. Both binary and probabilistic connections model were applied to identify the connectivity importance area. A value of 0.5 the probability of dispersal corresponding to the threshold dispersal distances considered (200m and 500m) in order to provide both models equivalent. In this analysis, a negative exponential function has been applied as a function of inter-patch edge-to-edge distance [31].

The habitat availability concept is based on considering a patch itself as a space where connectivity occurs, integrating habitat patch area and connections among different patches in a single measure [29]. This approach recognizes that for measuring connectivity in a meaningful way the connected habitats are existing within the patches themselves (intra-patch connectivity). In particular, this should be considered together with the area made available by the connections between habitat patches (inter-patch connectivity). For such analysis, connectivity metrics like LCP, IIC or PC are highly efficient [30] and have been applied in this analysis. A brief description of selected connectivity metrics has given as follows:

- LCP – Landscape coincidence probability ranges from 0 to 1, increases with improved connectivity and is computed as:

$$LCP = \sum_{i=1}^{NC} (C_i/A_L)^2 \tag{1}$$

where NC is the number of components in the landscape, C_i is the total component attribute (sum of the attributes of all the nodes belonging to that component), and A_L is the maximum landscape attribute. A_L is the total landscape area (area of the analyzed region, comprising both habitat and non-habitat patches). LCP=1 when all the landscape is occupied by habitat. In this case, LCP is defined in a similar way to CCP as the probability that two randomly points (or animals) located within the landscape (i.e., points can lie either in habitat or non-habitat areas).

- IIC – Integral index of connectivity is one of the widely accepted binary indexes for the functional connectivity analysis which represent several improved characteristics compared to other available binary indices [29, 32]. IIC ranges from 0 to 1 and increases with improved connectivity. Which can be computed as:

$$IIC = \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{a_i . a_j}{1+nl_{ij}}/A_L^2 \qquad (2)$$

where n is the total number of nodes in the landscape, a_i and a_j are the attributes of nodes i and j, nl_{ij} is the number of links in the shortest path (topological distance) between patches i and j, and A_L is the maximum landscape attribute. A_L is the total landscape area (area of the analyzed region, comprising both habitat and non-habitat patches) and IIC=1 when all the landscape is occupied by habitat.

- PC – Probability of connectivity is recommended as the best index for the type of connectivity [32]. PC is defined as the probability that two animals randomly placed within the landscape fall into habitat areas that are reachable from each other (interconnected) given a set of n habitat patches and the connections (p_{ij}) among them. It ranges from 0 to 1 and increases with the improve connectivity. It is given by:

$$PC = \sum_{i=1}^{n}\sum_{j=1}^{n} a_i . a_j . P_{ij}^{*}/A_L^2 \qquad (3)$$

where: n is the total number of habitat nodes in the landscape, $a_i i$ and a_j are the attributes of nodes i and j, A_L is the maximum landscape attribute, and p^*_{ij} is the maximum product probability of all paths between patches i and j. When two nodes are completely isolated from each other, either by being too distant or by existence of a land cover impeding the movement between both nodes (e.g. a road) then $p^*_{ij} = 0$, and when $i = j$ then $p^*_{ij} = 1$ (a node can be reached from itself with the highest probability).

All of the metrics suitable for the landscape level and with the increasing of the values indicate improved connectivity. Each of the connectivity metrics represents the connectivity importance of individual habitat patches. A consolidated importance value of each of the patches was calculated by the mean value of the three metrics. The importance values were then added with each of the habitat patch attributes using ArcGIS 9.3. Finally, all the values were classified into High, Medium and Low importance value classes and then illustrated into the spatially explicit map.

Results and Discussions

Landscape pattern analysis

Landscape size and shape metrics of different wildlife protected areas of the state of Selangor have been analyzed for the year 1988, 1996 and 2005. Bukit Nenas wildlife protected area shows a lower degree of fragmentation than other protected areas in the study area. A considerable proportion of its forest area disappeared in 1996 from the year 1988. This protected area designated for the conservation of birds and it is located in the heart of the capital Kuala Lumpur. Built-up area increased and number of patches of this land use type also increased. CA increased means the total proportion of built-up area has increased in 1996 and 2005. The values of TE and MPE are indicating that the significant proportion of forest being lost particularly in 1996 (Table 1). Landscape shape index MSI shows that built-up area become more compact and patches become more aggregated particularly in the year 2005 (Table 1 - *Landscape shape analysis*). The natural shape of forest patch changed due to the artificial structures grows around the edge of the forested area.

Table 1. Landscape pattern analysis of Bukit Nenas

Area analysis

Land use class	NP			CA (m^2)			MPS (m^2)		
	1988	1996	2005	1988	1996	2005	1988	1996	2005
Built-up Area	1	1	2	10030	45644	46218.17	10030	45644	23109.09
Forest	1	1	1	132200	82788	81014	132200	82788	81014
Paddy & Other Agriculture	2	3	4	28480.12	42300	43489	14240.06	14100	10872.25

Edge analysis

Land use class	TE(m)			MPE(m)		
	1988	1996	2005	1988	1996	2005
Built-up Area	1621.308	1155.078	2319.773	1621.308	1155.078	1159.887
Forest	3385.543	2584.141	2452.845	3385.543	2584.141	2452.845
Paddy & Other Agriculture	735.9249	853.56	832.19	367.96	284.52	208.05

Landscape shape analysis

Land use class	MSI			MPAR			MPFD		
	1988	1996	2005	1988	1996	2005	1988	1996	2005
Built-up Area	1.60438	1.59364	1.74045	0.062	0.055	0.054	1.43007	1.27545	1.390085
Forest	1.47553	1.357	1.323	0.051	0.05	0.053	1.27585	1.253	1.225
Paddy & Other Agriculture	1.43	1.50002	1.357455	0.131	0.113	0.092	1.303	1.320735	1.36807

Table 2. Landscape pattern analysis of Bukit Sungai Puteh

Area analysis

Land use class	NP			CA			MPS		
	1988	1996	2005	1988	1996	2005	1988	1996	2005
Built-up Area	2	3	1	87291	189631	861449	43646	63210.5	861448.5
Cleared Land	4	1	0	101828	13461	0	25457	13461.3	0
Commercial Agriculture	4	9	2	276674	346334	52671	69169	38481.6	26335.3
Forest	3	1	1	451804	300741	22300	150601	300741	22300
Paddy & Other Agriculture	0	8	2	0	67430	3478	0	8428.7	1739.2

Edge analysis

Land use class	TE			MPE		
	1988	1996	2005	1988	1996	2005
Built-up Area	2176.2	5629.8	5742.9	1088.1	1876.6	5742.9
Cleared Land	2582.9	719.5	0	645.7	719.5	0
Commercial Agriculture	5828.6	7343.1	1086.5	1457.2	815.9	543.2
Forest	4030.3	3746.4	2834.2	1343.4	3746.4	2834.2
Paddy & Other Agriculture	0	2883.2	320.5	0	360.4	160.2

Landscape shape analysis

Land use class	MSI			MPAR			MFRACT		
	1988	1996	2005	1988	1996	2005	1988	1996	2005
Built-up Area	1.561	1.896	1.745	0.048	0.047	0.007	1.348	1.355	1.267
Cleared Land	1.705	1.749	0	0.162	0.053	0	1.432	1.384	0
Commercial Agriculture	1.589	1.264	1.7	0.082	0.038	0.932	1.379	1.304	1.815
Forest	1.469	1.927	1.57	0.063	0.012	0.023	1.343	1.305	1.302
Paddy & Other Agriculture	0	1.23	1.343	0	0.073	0.333	0	1.351	1.564

Bukit Sungai Puteh has been experiencing a high degree of forest fragmentation despite it is situated with the Department of Wildlife and National Park (DWNP), Malaysia head office. There is a small fragment of forest has been struggling to survive from the high degree of anthropogenic pressure and could only save near to an acre of forest land. Built-up area increased alarmingly in this wildlife protected area. It is seen from the analysis that the CA of built-up area increased in a high rate (about three times in 1996 and ten times in 2005 than that of 1988) while forest area decreased reversibly. Plantation and commercial agriculture have developed significantly within the protected area. CA increased for modified ecosystems but reduced for natural ecosystems (Table 2). Edge analysis of the area is indicating the degree of habitat loss occurred over the last two decades. TE value of forest area decreases significantly which is due to the large decline of the forested area. NP reduces but TE increased for the built-up area, means the area enlarged and other land uses within this class converted into the built-up area. Landscape shape index MSI, MPAR and MFRACT show a simplified artificial edge in the forested area but in case of commercial agriculture it is showing a complex natural feature (Table 2 - *Landscape shape analysis*). This may be due to the shifting of forested area into the commercial agriculture and plantation area, so that the existing complex boundary remains with the shifted land use.

KL Golf Course has designated as wildlife protected area in 1923 under the Wild Animal and Bird Protection Enactment, 1921 as a bird sanctuary. There is no sign of forest in this protected area in any of the land use maps studied. Basically hedge rows are the shelter of many indigenous birds. In these classified land use/land cover maps hedge row and golf fields were classified as paddy and other agriculture land use. This wildlife protected area is situated at the center of highly urbanized Kuala Lumpur area. Landscape pattern analysis of the area shows no significant changes over the period of study. There is a slight increase in the built-up area in 2005. Paddy and other agriculture NP increased in 2005 while its CA area decreased by a little amount. Edge metrics TE and MPE show a little change in 2005. Landscape shape analysis shows that the landscape patterns remained stable in the study period without changing significantly (Table 3). Indexes of MSI, MPR and MFRACT remain similar over the three study year.

Table 3. Landscape pattern analysis of KL Golf Course

Area analysis

Land use class	**NP**			**CA**			**MPS**		
	1988	**1996**	**2005**	**1988**	**1996**	**2005**	**1988**	**1996**	**2005**
Built-up Area	1	1	1	293523	259855	400924	293523	259855	400924
Cleared Land	1	0	0	6250	0	0	6250	0	0
Paddy & Other Agriculture	1	1	2	1719356	1759274	1618205	1719356	1759274	809102.5

Edge analysis

Land use class	**TE**			**MPE**		
	1988	**1996**	**2005**	**1988**	**1996**	**2005**
Built-up Area	6950.7	6526.9	8778.1	6950.7	6526.9	8778.1
Cleared Land	396.9	0	0	396.9	0	0
Paddy & Other Agriculture	6550	6664.1	6315.1	6550	6664.1	2105

Landscape shape analysis

Land use class	**MSI**			**MPAR**			**MFRACT**		
	1988	**1996**	**2005**	**1988**	**1996**	**2005**	**1988**	**1996**	**2005**
Built-up Area	1.61914	1.6119	1.71081	0.435	0.429	0.454	1.40537	1.40901	1.40759
Cleared Land	1.41641	0	0	0.054	0	0	1.36924	0	0
Paddy & Other Agriculture	1.40913	1.41733	1.59936	0.076	0.085	0.081	1.22406	1.22451	1.45991

It is clear from the spatial analyses of these three protected areas that, forest land use is gradually decreasing and shifting to other land uses. CA values for artificial or modified land uses for example, built-up area, paddy and other agriculture, commercial agriculture, have increased significantly. On the other hand, CA values have decreased alarmingly of the forest land use in all the protected areas. Landscape edge and shape metrics show forest patches have become fragmented and lost their naturalness in terms of their natural shape curvature (Table 1, 2 and 3).

Landscape connectivity

It has been suggested that landscape connectivity should be considered within the wider concept of habitat availability in order to be successfully integrated in landscape planning application [29]. Therefore, node importance values of the landscape metrics LCP, IIC and PC were measured and their average values were calculated to measure the importance of each of the nodes (habitat patches) in the study area. Overall connectivity indices values show clear differences among the different distance thresholds observed (Table 4). It was assumed that, as the patches are quite scattered in this highly developed Kuala Lumpur city area, it is more rationale to reduce the distance threshold. Therefore, 200m and 500m distance threshold was examined besides 2, 4 and 5km distances. The result also revealed that, the patches in this zone are quite scattered. Therefore, metric values show a great variation with different distance thresholds. Figure 2 represents High, Medium and Low importance value of landscape connectivity in the study area. While protected areas shape file overlaid with the map, it can be easily compared how the protected areas representing critical connectivity areas. It is evident from the analysis that almost all of the important area of landscape connectivity remain outside the protected areas of the study region. In many cases, many of the important habitat patches have a great potential of landscape connectivity even inside the highly developed areas of Kuala Lumpur conurbation (inside the red circle showing on the Figure 2). Which means, landscape connectivity approaches, for example, corridor, stepping stones, highway over passes and under passes can be constructed to improve the connectivity of habitat patches in the region. Whereas, the existing protected areas remain in the low connectivity important area. Moreover, the habitat patches represented by the existing protected areas have become isolated. Therefore, these areas are gradually losing its carrying capacity to support ecological integrity.

Table 4. Overall connectivity metrics values showing variations in the dispersal distances of 200 m, 500 m, 2 km, 4 km and 5 km

Metric	**Overall metric value**				
	200 m	**500 m**	**2 km**	**4 km**	**5 km**
LCPnum	61572368	68184168	107269384	134424832	217444880
IICnum	58434340	59928964	73444744	80144696	90226224
PCnum	61909280	67624590	90100000	106000000	112000000

Most of the research on landscape pattern metrics has focused on describing the variations of overall metrics values and not on the planning decisions. Therefore, landscape patch prioritization analysis is important for conservation planning and existing protected area evaluation. In general, wildlife protected areas of the study area found located in the less priority area and even far away from the priority areas. Therefore, this spatially explicit map can be helpful for effective and representing protected area network planning. Moreover, this map also has high potential in helping numerous agencies to plan for the conservation and sustainable development planning of the city. The similar methods may be applied for different potential conservation sites in the tropical region and they are helpful for the site scales, landscapes to the regional scales.

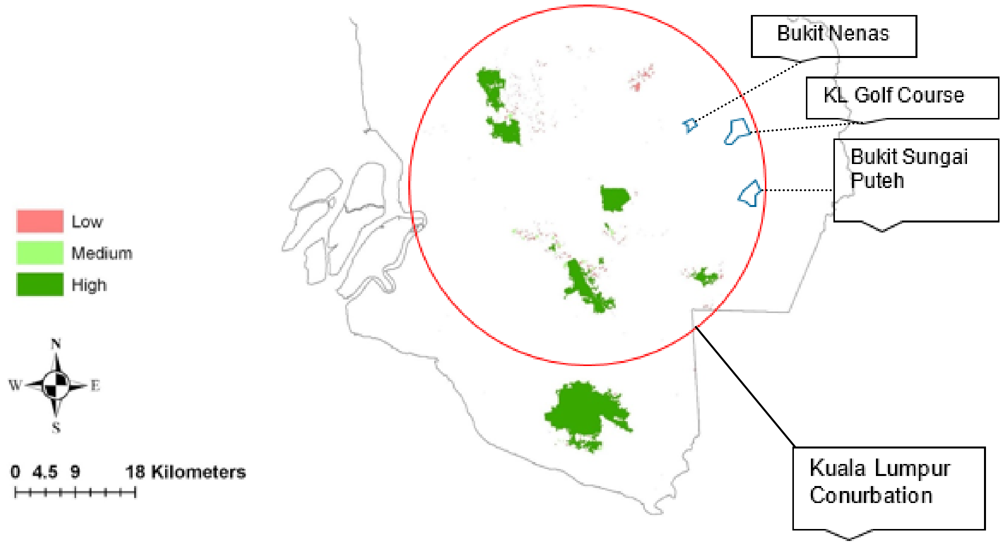

Fig. 2. Connectivity importance map of the Kuala Lumpur Conurbation shows the important forest patches for conservation planning

Conclusion

As more and more of the world become urbanized, the question of whether the urban area can provide an impression of naturalness or maintain ecological integrity for a sustainable healthy city is growing [2, 33]. Therefore, urban planners are, now a days, concerning habitat composition, structure, and function for the sustainable city planning. The question of how one might measure ecological integrity in urban landscapes is still a dilemma for many concerned in the field [34]. However, ensuring such ecological integrity is certainly important for nature conservation and urban planning in the cities like Kuala Lumpur [2]. Furthermore, a systematic scientific evaluation is required in such cases as some decision support criteria for the planners [35, 36]. Many are suggesting, study on the landscape spatial pattern and landscape connectivity can provide necessary information for development of a suitable approach for nature conservation particularly for the urban landscapes [11, 33]. Therefore, this study can be able to play a part in the systematic analysis to facilitate the sustainable urban planning.

Landscape spatial pattern analysis shows that much attention hasn't given for the conservation of naturalness in this study area over the last few decades. Many natural areas, both inside and outside of protected areas, have become fragmented, isolated, and disappeared within the study period [37]. Though, protected areas have been established to reduce the risk of disappearance of natural areas, but they are experiencing severe threats from anthropogenic activities. It is also worth mentioning that the evaluation of whether these protected areas are working hadn't done significantly. In many cases, they remain far from the reality in compare to their management goal rather standing as *"paper parks"*. In spite of these anthropogenic pressure and hasty urban sprawl many potential habitat areas for critical flora and fauna still exist in this study region. Landscape connectivity analysis shows that there are some remnant habitats still bearing connectivity importance. Therefore, it is an urgent need to designate these potential areas as protected area. It is also required to prioritize potential areas as the conservation site for safeguarding critical flora and fauna based on their conservation values. Indeed, this process will play a significant role for the sustainable planning of the Kuala Lumpur city.

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References

[1] * * *, **World Urbanization Prospects: The 2005 Revision,** United Nations, Department of Economic and Social Affairs, Population Division, New York, 2005.

[2] S.T. Shathy, M.I.H. Reza, *Sustainable Cities: A Proposed Environmental Integrity Index (EII) for Decision Making*, **Frontiers in Environmental Science**, **4**, 2016, p. 82, doi: 10.3389/fenvs.2016.00082

[3] R. Forman, **Urban Regions: Ecology and Planning Beyond the City**, Cambridge University Press, New York, 2008.

[4] I. Kuhn, W. Durka, S. Klotz, *BiolFlor - A New Plant-Trait Database as a Tool for Plant Invasion Ecology*, **Diversity and Distribution**, **10**(5-6), 2004, pp. 363-365.

[5] M. Pautasso, *Scale Dependence of the Correlation Between Human Population Presence and Vertebrate and Plant Species Richness*, **Ecology Letters**, **10**(1), 2007, pp. 16-24.

[6] D. Stasch, K. Stahr, **Boden- und Flachen Ressourcen - Management of Urban Soil Resources and of Urban Land Use,** Preliminary report of BWPLUS, Forschungzentrum, Karlsruhe, 1999.

[7] R.I. Mcdonald, R.T.T. Forman, P. Kareiva, R. Neugarten, D. Salzer, J. Fisher, *Urban Effects, Distance, and Protected Areas in an Urbanizing World*, **Landscape and Urban Planning**, **93**(1), 2009, pp. 63-75.

[8] * * *, **Natural Resource Challenge - The National Park Service's Action Plan for Preserving Natural Resources**, U.S. Department of the Interior, National Park Service, Natural Resource Stewardship and Science Washington DC, 1999.

[9] A.J. Hansen, J.J. Rotella, *Biophysical Factors, Land Use, and Species Viability in and Around Nature Reserves*, **Conservation Biology**, **16**(4), 2002, pp. 1112-1122.

[10] R. DeFries, A. Hansen, B.L. Turner, R. Reid, J.G. Liu, *Land Use Change Around Protected Areas: Management to Balance Human Needs and Ecological Function*, **Ecological Applications**, **17**(4), 2007, pp. 1031-1038.

[11] P.A. Townsend, T.R. Lookingbill, C.C. Kingdon, R.H. Gardner, *Spatial Pattern Analysis for Monitoring Protected Areas*, **Remote Sensing of Environment**, **113**(7), 2009, pp. 1410-1420.

[12] L. Fahrig, *Effects of Habitat Fragmentation on Biodiversity*, **Annual Review of Ecology Evolution and Systematics**, **34**, 2003, pp. 487-515.

[13] M.I.H. Reza, S.A. Abdullah, *Regional Index of Ecological Integrity: A Need For Sustainable Management of Natural Resources*, **Ecological Indicators**, **11**(2), 2011, pp. 220-229.

[14] Economic Planning Unit, Malaysia, **Projected Population in 2010 Based on the Population Census 2000 by The Department of Statistics, Malaysia,** 2010, http://www.statistics.gov.my/portal. See also the pdf document from the Economic Planning Unit, Malaysia following the link http://www.epu.gov.my/html/themes/epu/images/common/pdf/eco_stat/pdf/1.2.5.pdf (accessed 16 January 2017).

[15] J.R. Jensen, **Introductory Digital Image Processing: A Remote Sensing Perspective**, Second Edition, Prentice Hall Series in Geographic Information Science, Upper Saddle River, New Jersey, USAS, 1996.

[16] S. Lang, D. Tiede, *^{v}LATE Extension fur ArcGIS - Vektorbasiertes Tool Zur Quantitativen Landschaftsstrukturanalyse*, **Proceedings ESRI 2003**. **18th User Conference**, Anwenderkonferenz, Innsbruck, 2003.
[17] K. McGarigal, B.J. Marks, **FRAGSTATS: Spatial Pattern Analysis Program for Quantifying Landscape Structure**, Gen. Tech. Report PNW-GTR-351, U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, OR, 1995, p. 122.
[18] D. Armenteras, F. Gast, H. Villareal, *Andean Forest Fragmentation and the Representativeness of Protected Areas in the Eastern Andes, Colombia*, **Biological Conservation**, **113**(2), 2003, pp. 245-256.
[19] D.R. Patton, *A Diversity Index for Quantifying Habitat Edge*, **Wildlife Society Bulletin, 3**(4), 1975, pp. 171-173.
[20] J.R. Krummel, R.H. Gardner, G. Sugihara, R.V. O'Neill, P.R. Coleman, *Landscape Patterns in a Disturbed Environment,* **Oikos**, **48(3)**, 1987, pp. 321-324.
[21] M.G. Turner, C.L. Ruscher, *Changes in Landscape Patterns in Georgia, USA*, **Landscape Ecology**, **1**(4), 1988, pp. 241-251.
[22] W.J. Ripple, G.A. Bradshaw, T.A. Spies, *Measuring Forest Landscape Patterns in the Cascade Range of Oregon, USA,* **Biological Conservation**, **57**(1), 1991, pp. 73-88.
[23] M.F. Barnsley, R.L. Devaney, B.B. Mandelbrot, H.O. Peitgen, D. Saupe, R.F. Voss, (editors: H.O. Peitgen, D. Saupe), **The Science of Fractal Images**, Springer-Verlag, New York, 1988.
[24] M.F. Barnsley, **Fractals Everywhere**, Academic Press, London, 1993.
[25] J.F. Gouyet, **Physics and Fractal Structures**, Springer, New York, 1996.
[26] C.M. Hagerhall, T. Purcell, R. Taylor, *Fractal Dimension of Landscape Silhouette Outlines as a Predictor of Landscape Preference,* **Journal of Environmental Psychology**, **24**(2), 2004, pp. 247-255.
[27] L. Pascual-Hortal, S. Saura, *Impact of Spatial Scale on the Identification of Critical Habitat Patches for the Maintanence of Landscape Connectivity,* **Landscape and Urban Planning**, **83**(2-3), 2007, pp 176-186.
[28] F. Jordan, A. Baldi, K.M., Orci, I. Racz, Z. Varga, *Characterizing the Importance of Habitat Patches and Corridors in Maintaining the Landscape Connectivity of a Pholidoptera Transsylvanica (Orthoptera) Metapopulation,* **Landscape Ecology**, **18**(1), 2003, pp. 83-92.
[29] L. Pascual-Hortal, S. Saura, *Comparison and Development of New Graph-Based Landscape Connectivity Indices: Towards the Priorization of Habitat Patches and Corridors for Conservation*, **Landscape Ecology**, **21**(7), 2006, pp. 959-967.
[30] S. Saura, Torne, J. *Conefor Sensinode 2.2: A Software Package for Quantifying the Importance of Habitat Patches for Landscape Connectivity,* **Environmental Modelling & Software, 24**(1), 2009, pp. 135-139.
[31] D. Urban, T. Keitt, *Landscape Connectivity: a Graph-Theoretic Perspective*, **Ecology**, **82**(5), 2001, pp. 1205-1218.
[32] S. Saura, L. Pascual-Hortal, *A New Habitat Availability Index to Integrate Connectivity in Landscape Conservation Planning: Comparison with Existing Indices and Application to a Case Study,* **Landscape and Urban Planning, 83**(2-3), 2007, pp. 91-103.
[33] R.F. Noss, *Can Urban Areas Have Ecological Integrity?,* **Proceedings of 4th International Symposium on Urban Wildlife Conservation**, pp. 3-8, 2004.
[34] M.I.H. Reza, *Importance and Considerations to Develop a Composite Index of Ecological Integrity for Ecological Management,* **International Journal of Ecology and Development, 28**(2), 2014, pp. 32-48.
[35] C.R. Margules, R.L. Pressey, *Systematic Conservation Planning*, **Nature**, **405**(6783), 2000, pp. 243-253.

[36] C. Brauniger, S. Knapp, I. Kuhn, S. Klotz, *Testing Taxonomic and Landscape Surrogates for Biodiversity in an Urban Setting*, **Landscape and Urban Planning**, **97**(4), 2010, pp. 283-295.
[37] M.I.H. Reza, *Measuring Forest Fragmentation in the Protected Area System of a Rapidly Developing Southeast Asian Tropical Region,* **Science Postprint, 1**(1), 2014, e00030, doi: 10.14340/spp.2014.09A0001.

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