Land use change and fragmentation in the protected areas of peninsular Malaysia: The cases of Klang Gate and Sungai Dusun wildlife reserves

W H Lee1*, S A Abdullah1 and N H Rafaai1

1Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia 43600 UKM Bangi, Selangor, Malaysia.

*Corresponding author: nicole_kwy@yahoo.com

Abstract. Ongoing economic and demographic growth in developing countries has exponentially increased the need for anthropogenic land use. The expansion of human populations into pristine environments has publicized the fierce competition between environmental conservation and anthropogenic resource demands. Because protected areas (PAs) are increasingly imperilled by human land use, particularly in the tropical regions, PAs should be regularly monitored and assessed for land use modifications in order to determine the impact on long term sustainability. In this work, land use change assessments and forest fragmentation analysis were conducted for the period between 1988 and 2012 at two PAs in peninsular Malaysia — Klang Gate and Sungai Dusun wildlife reserve. The findings demonstrated that Klang Gate lost 29.9% of its forest cover due to surrounding development and commercial agriculture; while commercial agriculture in Sungai Dusun caused only a 5% forest loss. Furthermore, Klang Gate also showed a higher degree of forest fragmentation when compared to Sungai Dusun. The fact that Klang Gate experienced ~6x more habitat loss than Sungai Dusun implies that area underwent unsustainable development. Thus, more in depth evaluation regarding the effectiveness of conservation measures within PAs of developing countries is crucial to identifying gaps in management and conservation policy.

1. Introduction

Over the past two decades, there has been a significant increase in the number of PAs worldwide, as scientists and governments attempt to protect their country and continent’s remaining biodiversity, before it’s completely destroyed by irresponsible development and other human activities [1,2]. Due to increasing conservation measures, to date, PAs account for ~15% of global terrestrial and inland water environments. However, additional investment and support is required to reach the 2020 target of 17% coverage, outlined in the Convention on Biological Diversity (CBD) [3]. Nevertheless, despite these conservation efforts, rich natural heritage in Asia, and specifically Southeast Asia, is still imperilled by extensive anthropogenic threats, primarily habitat loss and environmental degradation [4,5].

The habitat loss and environmental degradation are directly correlated to anthropogenic land use – particularly forest fragmentation and natural vegetation destruction – as they produce significant landscape changes within the PAs [6]. In essence, the needs of a continuously expanding population and the incentives to promote economic growth are completely at odds with the goals of global PA network...
expansion; and intense competition has developed between environmental conservation and anthropogenic resource demands [7]. This conflict is especially prevalent in rapidly developing countries, like Peninsular Malaysia.

Peninsular Malaysia is among the world's most biologically diverse regions and is one of the fastest developing countries. While Peninsular Malaysia harbours many tropical species, evidence suggests that tropical forests in this region are undergoing significant land use and landscape alterations, putting many species at risk for extinction due to detrimental anthropogenic activity (e.g. [8,9]). For this reason, the 2016 – 2025 National Policy on Biological Diversity is focused on addressing the direct and indirect pressures affecting biodiversity in order to safeguard the ecosystem and species diversity [10].

To date, studies that analyse and evaluate land use and landscape alteration in the PAs of developing countries are still scarce, which prevents effective planning and management of these sites and limits the ability to effectively strategize an integrated and comprehensive approach to land use planning. Thus, whether or not PAs in developing regions will be mildly, moderately, or severely affected by residential, agricultural, and industrial expansion, remains unknown. As such, the objective of this study is to analyse the land use and forest fragmentation of two PAs in Selangor state, Peninsular Malaysia, in order to evaluate the effects of increasing anthropogenic influence between the years 1988 and 2012. Two wildlife reserves were selected as case studies— Klang Gate wildlife reserves (hereafter referred to as Klang Gate) and Sungai Dusun wildlife reserves (hereafter referred to as Sungai Dusun). The terms wildlife reserve and protected area are used interchangeably throughout this work, as wildlife reserve is a type of PA that is established primarily for wildlife protection and biodiversity conservation.

2. Materials and methods

2.1. Study sites

The two selected wildlife reserves are located in Selangor State (Table 1) — the most developed and populous state in Peninsular Malaysia (figure 1). It also yields the highest gross domestic product per capita [11]. This state has a highly diversified economy; composed of agriculture, manufacturing, industry, commerce, and tourism. Therefore, extensive study in this state is essential to enhancing the land use planning and conservation effort.

| Wildlife Protected Areas | IUCN Category | Land Area Management | Area (ha) | Location | Elevation (meter above sea level) |
|--------------------------|---------------|----------------------|-----------|----------|----------------------------------|
| Klang Gate               | VI            | DWNP                 | 1348      | 3°12'–3°16'N & 101°43'–101°46'E | 130 – 400                       |
| Sungai Dusun             | Ib            | DWNP                 | 5113      | 3°39'–3°42'N & 101°20'–101°29'E | 25 – 253                        |

aDepartment of Wildlife and National Parks.
bIUCN category VI – Wilderness area.
cIUCN category Ib – Protected area with sustainable use of natural resources.

Klang Gate was selected as a study site because it is a PA located adjacent to an urbanizing area. As such, it makes an ideal place to evaluate: 1) the effects of development and urbanization pressures on a conservation site, and 2) the effectiveness of current conservation measures in protecting the PAs against development and urbanization pressures. Additionally, Klang Gate supports a quartz ridge more than 14 km long and 200 m wide, which is considered one of the most unique geologic formations in Malaysia. This ridge also hosts five endemic plant species – *Aleisanthia rupestris*, *Borreria pilulifera*, *Eulalia milsumii*, *Henckelia primulina*, and *Ilex praetermissa* [12,13] and an endangered animal called the Sumatran serow (*Capricornis sumatraensis*) [14]. Sungai Dusun was selected as the second study site because it is also a strictly PA, but is surrounded only by oil palm plantations and is likely to be affected exclusively by agricultural development. Furthermore, endangered species such as the Malayan tapir (*Tapirus indicus*) and the white-handed gibbon (*Hylobates lar*) also exist within the reserve. Hence,
Klang Gate and Sungai Dusun are both critical refuges for biodiversity surrounded by different levels of encroaching development. As such, they represent an excellent opportunity to evaluate how well these PAs resist the surrounding land use change pressure.

![Figure 1. Location of two study sites in Selangor state.](image)

2.2. Data source and processing of images
A 1988 land use map of Klang Gate and Sungai Dusun was obtained from the Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia (refer to [15,16]). The map was compiled using 30m Landsat Thematic Mapper (TM) images. The 2012 land use maps of the reserves were obtained from the Malaysian Remote Sensing Agency (MRSA). The maps were based on 10m resolution SPOT 5 images that were processed using ERDAS Imagine 9.1 software.

The SPOT 5 satellite images were geo-corrected to align with the GCS Kertau coordinate system. After creating a mosaic out of the individual images, boundaries were delineated to identify the area that defined the PAs. Bands of spectral data were combined to generated band combinations that enhance interpretation and differentiation of various land uses of interest. A false colour composite of band combination 4-3-2 was applied to the images. Finally, the images were classified using supervised classification that was primarily controlled by the analyst [17,18]. The land use classifications for the 1988 Landsat TM imagery included: built-up area, cleared land, commercial agriculture, paddy and other agriculture, water body, and forest. The same classification system was used for the 2012 SPOT 5 imagery. Classification accuracy was assessed by calculating the overall accuracy, \( po \), and the kappa coefficient, \( k \). The overall classification accuracies for Klang Gate and Sungai Dusun were 88.28% and 83.59%, respectively, and \( k \) were 0.84 and 0.80, respectively.
2.3. Data analysis
Fragmentation analysis was conducted on both study sites. However, to account for differences in the spatial resolution of the 1988 (30m resolution) and 2012 (10m resolution) maps, 2012 data was resampled using the nearest neighbour algorithm to a 30m resolution.

Fragmentation was analysed using GUIDOS, a standalone freeware toolbox [19]. Details of this fragmentation analysis method are reported in [20]. The raster images for each study site were analysed based on seven geometric categories [21,22]: core, islet, loop, bridge, perforation, edge, and branch (refer to [20] for category definitions). Once the category percentage was finalized, equation (1) was used to quantify the degree of fragmentation:

\[ F = 100 - [C - (I + P + E + B + R + L)] \]

where \( F \) is the percentage of total fragmentation; \( C \) represents the percentage of the core area; \( I, P, E, B, R, \) and \( L \) represent the percentage of the islet area, perforated area, edge area, branch area, bridge area, and loop area, respectively. An \( F \) value of 100 indicates the highest fragmentation, whereas 0 implies that the protected area is fragmentation free.

3. Results and discussion

3.1 Land use change at Klang Gate from 1988 – 2012
Land use categories identified at Klang Gate in 1988 consisted of forest, water body, built-up area, and cleared land. Forest dominated the land use in Klang Gate for both years, with 87.21% in 1988 and 57.32% in 2012 (figure 2, table 2). In 1988, forest coverage was followed by water body (11.67%); and the remaining land uses - cleared land and built-up area - represented less than 2% of the total land use (figure 2a). However, by 2012, built-up area became the second highest land use (15.61%) followed by commercial agriculture (13.31%) and the water body (12.79%).

![Figure 2. Land use map for Klang Gate at 1988 (a) and 2012 (b).](image-url)
Table 2. Land use distribution of Klang Gate and Sungai Dusun from 1988 – 2012.

| Land use types          | Klang Gate       | Sungai Dusun     | Annual change rate |
|-------------------------|------------------|------------------|--------------------|
|                         | 1988 (%)         | 2012 (%)         | % Changes          | 1988 (%) | 2012 (%) | % Changes |
|                         |                  |                  |                    |          |          |          |
| Forest                  | 87.22            | 57.32            | – (34.28)          | 98.04    | 93.02    | – (5.12) |
| Water body              | 11.67            | 12.79            | + (9.60)           | 0        | 0        | 0        |
| Commercial agriculture  | 0                | 13.31            | + (100)            | 1.96     | 6.80     | + (247.45) |
| Paddy and other agriculture | 0            | 0.97             | + (100)            | 0        | 0.18     | + (100) |
| Built-up area           | 0.07             | 15.61            | + (22,200)         | 0        | 0        | 0        |
| Cleared land            | 1.04             | 0                | – (100)            | 0        | 0        | 0        |

Land use changes between 1988 and 2012 show that forest cover and cleared land reduced throughout this period, in which forest cover declined by a remarkably 29.9%, while cleared land only slightly declined by 1.04% (figures 2b and 3). Both forest cover and cleared land show negative trends (–34.28% and –100%, respectively). Apart from these two land use categories, the coverage of other land uses increased, demonstrating a positive trend over the 24–year period (Table 2). Built-up area increased 15.54%, depicting the largest increase among all the categories and it shows a positive change (22,200%) (Table 2). The built-up area’s annual rate of change was 0.65% while the remaining land uses showed less than 0.1% annual rate of change (Table 2).

3.2 Land use change at Sungai Dusun from 1988 – 2012
Land use categories identified at Sungai Dusun in 1988 included only forest and commercial agriculture. This wildlife reserve was predominantly covered by forest (98.04%), whereas commercial agriculture occupied only 1.96% of the total land use (figure 4a, table 2). By 2012, built-up area was introduced to Sungai Dusun and contributed to 0.18% of the land use (Figure 4b). Forest cover in this reserve presented a negative pattern of change (–5.12%) and dropped to 93.02% during the study period (Figure 4b, Table 2). While forest cover dropped 5.02%, commercial agriculture and built-up area increased to 4.84% and 0.18%, respectively (Figure 3). Therefore, commercial agriculture and built-up area show a positive change pattern (+247.45% and +100%) (Table 2). Since the magnitude of change for each land use is generally low, their annual rate of change was less than 0.3%.

Figure 3. Relative change of percentage in land use for Klang Gate and Sungai Dusun. F – forest; W – water; CA – commercial agriculture; POA – paddy and other agriculture; BU – built-up area; CL – cleared land.
3.3 Overall land use pattern at Klang Gate and Sungai Dusun from 1988 – 2012

In Klang Gate, forest cover loss and agricultural land growth were both observed throughout the temporal study period. These results imply that socio-economic growth has adversely impacted this reserve. The land use and land cover changes demonstrate that the dynamic and complex interactions between structural and behavioural factors associated with social, technological, and infrastructure capacity demands; and the biophysical attributes of the area can and have become so unbalanced that they eventually affect the environmental health of the ecosystem [23,24]. The increase in population growth exerts pressure on limited natural resources and subsequently contributes to various negative land use changes in order to meet anthropogenic demand [23,25].

This scenario was observed at Klang Gate, where agricultural land encroached closer to the PA core and was followed by built-up area at the frontiers; resulting in ~30% forest loss within a 24–year period. Furthermore, land use policy is one of the most prominent factors that influence land use within wildlife reserves. In the early years after national independence, land development policies in Peninsular Malaysia strongly favoured agricultural expansion (i.e., rubber and oil palm plantation); that trend changed in the 1980s to supporting development of manufacturing. As one of the most rapidly developing states, Selangor state exemplifies the national policies. Urban development at Kuala Lumpur city centre progressed rapidly and intensely; and facilities, residential areas, and industrial sectors have made it a centre of development [24]. Klang Gate is located in close proximity to Kuala Lumpur city centre; therefore, the human impact and encroachment are stronger compared to the PAs located far from developing areas.

Sungai Dusun shows ~5% forest loss over the past two decades, primarily due to encroachment of oil palm plantations in the southeast region. Sungai Dusun is bounded by several Federal Land Development Authority (FELDA) projects that converted forest to oil palm plantations. Examples include, but are not limited to, Lima Belas Estate, FELDA Gedangsa and FELDA Soeharto to the north, and FELDA Sungai Tenggi to the east. This reserve is located far away from high population density. Moreover, the biophysical conditions, i.e., soil, geography, drainage condition, proximity to water resources, and suitability to be converted to agriculture or settlement determines appropriate land use of this reserve [24,26]. Sungai Dusun is characterised by the presence of lowland dipterocarp and fresh water peat swamp forest with an elevation distribution between 25 and 253 m.a.s.l. Hence, topography of this reserve is suitable for commercial plantation as opposed to high population settlement.

3.4 Landscape pattern change of Klang Gate and Sungai Dusun from 1988 – 2012

![Land use map for Sungai Dusun at 1988 (a) and 2012 (b).](image)
Landscape pattern changes in the wildlife reserves were assessed using fragmentation analysis. Fragmentation in Klang Gate increased from 7.06% in 1988 to 35.39% in 2012 (Figure 5). Fragmentation in Sungai Dusun was 9.41% in 1988 - slightly higher than Klang Gate – but increased only to 14.39% by 2012. Hence, 2012 fragmentation of Klang Gate was significantly higher than that of Sungai Dusun.

Inevitably, fragmentation significantly increases the edge width of the PAs and creates negative edge impacts (e.g. fluxes of radiation, wind and water and lead to microclimate change) [27,28]. Subsequently, fragmentation can lead to isolation and habitat loss, which adversely effects biodiversity [29], such as local extinction to species that depend on large, intact forest. Furthermore, when humans fragment forests and take over land for anthropogenic use in the PAs, other anthropogenic threats emerge, such as poaching, excessive resources extraction, human-induced forest fires, and introduction of invasive species. As such, this assessment of land use change using remote sensing data is likely an underestimate of the actual loss in ecological integrity; as this method fails to account for human impacts that can’t be evaluated on a landscape scale.

4. Conclusion
In this study, land use changes were reported within Klang Gate and Sungai Dusun. Agricultural expansion and residential growth that resulted from the urbanizing processes at the nearest city— Kuala Lumpur, were predominantly increasing human impacts and fragmentation within these PAs. These unsustainable anthropogenic influence in the highly developing region could cause habitat loss, ecological integrity degradation, conservation capacity decline, wildlife movement inhibition, and eventually leads to biodiversity loss in the PAs. Since wildlife movement and flow are not confined to any physical boundaries of a PA, more in-depth evaluation regarding the land use at the PA surroundings is crucial to quantify their integrity. Furthermore, appropriate collaboration between policy makers and other stakeholders (e.g., park managers, scientists, land tenures, local communities and NGO) is necessary to halt the land conversion in PAs and initiate forest restoration in the PAs that were degraded by human land use.

5. References
[1] Locke H and Dearden P 2005 Rethinking protected area categories and the new paradigm Environ. Conserv. 32 1–10
[2] Saviano M, Di Nauta P, Montella M and Sciarelli F 2018 Managing protected areas as cultural landscapes: The case of the Alta Murgia National Park in Italy Land Use Policy 76 290–9
[3] UNEP-WCMC, IUCN 2016 Protected Planet Report 2016 (Cambridge UK and Gland, Switzerland: UNEP-WCMC and IUCN) pp 30
[4] Juffe-Bignoli D, Bhatt S, Park S, Eassom A, Belle E M S, Murti R, Buyck C, Raza Rizvi A, Rao M, Lewis E, MacSharry B and Kingston, N 2014 *Asia Protected Planet Report 2014* (Cambridge: UNEP-WCMC)

[5] Wilkinson C L, Yeo D C J, Tan H, Fikri A H and Ewers R M 2018 Land-use change is associated with a significant loss of freshwater fish species and functional richness in Sabah, Malaysia *Biol. Conserv.* 222 164–171

[6] Verburg P H, Overmars K P, Huigen M G A, Groot W T De and Veldkamp A 2006 Analysis of the effects of land use change on protected areas in the Philippines. *Appl. Geogr.* 26 153–173

[7] Gross D, Dubois G, Pekel J F, Mayaux P, Holmgren M, Prins H T, Rondinini C and Boitani L 2013 Monitoring land cover changes in African protected areas in the 21st century *Ecol. Inform.* 14 31–37

[8] Abdullah S A, Nor S M and Yusof A M 2014 Understanding development trends and landscape changes of protected areas in peninsular Malaysia: a much needed component of sustainable conservation planning (eds) Nakagoshi N, Mabuhay J A, *Designing Low Carbon Societies in Landscapes, Ecological Research Monographs* (Japan: Springer) pp 205–222

[9] Aiken S R 1994 Peninsular Malaysia’s protected areas’ coverage, 1903-92: creation, rescission, excision, and intrusion *Environ. Conserv* 21 49–56

[10] Ministry of Natural Resources and Environment (NRE) 2016 *National Policy on Biological Diversity 2016 – 2025* (Putrajaya: NRE)

[11] Abdullah S A and Nakagoshi N 2006 Changes in landscape spatial pattern in the highly developing state of Selangor, peninsular Malaysia *Landsc. Urban Plan.* 77 263–275

[12] Reid J A 1951 Klang Gates and Bukit Takun: Reflections of an Amateur Botanist. *Malayan Nature Journal* 5 109–123

[13] Kiew R 1982 The Klang Gates ridge *Malay Nat* 36 22–28

[14] Perumal B 1992 *Management Survey of Klang Gates Wildlife Sanctuary* (Petaling Jaya: WWF Malaysia)

[15] Reza M I H 2014 Measuring forest fragmentation in the protected area system of a rapidly developing Southeast Asian tropical region *Science Postprint* 1 1–7

[16] Reza M I H, Abdullah S A, Nor S B M and Ismail M H 2013 Integrating GIS and expert judgment in a multi-criteria analysis to map and develop a habitat suitability index: A case study of large mammals on the Malayan Peninsula *Ecol. Indic.* 34 149–158

[17] Bailey K M, Mcclerey R A, Binford M W, Zweig C, Bailey K M, Mcclerey R A, Binford M W, et al 2016 Land-cover change within and around protected areas in a biodiversity hotspot *J. Land Use Sci.* 11 154–176

[18] Eastman J R 2001 *Idrisi 32 release 2 guide to GIS and image processing vol 1* (Worcester: Clark University)

[19] European Commission 2019 Guidos Toolbox (GTB). https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/ (online 20 December 2017).

[20] Clay E, Moreno-Sanchez R, Torres-Rojo J M and Moreno-Sanchez F 2016 National assessment of the fragmentation levels and fragmentation-class transitions of the forests in Mexico for 2002, 2008 and 2013 *Forests* 7 6–8

[21] Soille P and Vogt P 2009 Morphological segmentation of binary patterns *Pattern Recognit. Lett.* 30 456–459

[22] Wickham J D, Ritters K H, Wade T G and Vogt P 2010. A national assessment of green infrastructure and change for the conterminous United States using morphological image processing *Landsc. Urban Plan.* 94 186–195

[23] Islam K, Jashimuddin M, Nath B and Nath T K 2018 Land use classification and change detection by using multi-temporal remotely sensed imagery: The case of Chunati wildlife sanctuary, Bangladesh *Egyptian Journal of Remote Sensing and Space Science* 21 37–47

[24] Verburg P H, Ritsema van Eck J R, de Nijs T C M, Dijst M J and Schot P 2004 Determinants of land-use change patterns in the Netherlands. *Environ. Plann. B Plann. Des.* 31 125–150
[25] Lambin E F, Turner B L, Geist H J, Agbola S B, Angelsen A, Folke C, Bruce J W, Coomes O T, Dirzo R, Fischer G, Folke C, George P S, Homewood K, Imbernon J, Leemans R, Li X, Moran E F, Mortimore M, Ramakrishnan P S, Richards J F, Skånes H, Steffen W, Stone G D, Svedin U, Veldkamp T A, Vogel C, Xu J 2001 The causes of land-use and land-cover change: moving beyond the myths. Global Environ. Chang. 11 261–269

[26] Krishnadas M, Agarwala M, Sridhara S and Eastwood E 2018 Parks protect forest cover in a tropical biodiversity hotspot, but high human population densities can limit success Biol. Conserv. 223 147–155

[27] Estreguil C and Mouton C 2009 Measuring and reporting on forest landscape pattern, fragmentation and connectivity in Europe: methods and indicators (Italy: JRC Scientific and Technical Reports Office for Official) pp 7–8

[28] Sauders D A, Hobbs R J and Margules C R 1991 Biological consequences of ecosystem fragmentation: A review Conserv. Biol. 5 18–32

[29] Fahrig L 2003 Effects of habitat fragmentation on biodiversity Annu. Rev. Ecol. Evol. Syst. 34 487–515

Acknowledgments
The authors wish to acknowledge assistance and encouragement from the officers of the Department of Wildlife and National Parks (DWNP) and other Ph.D. candidates from LESTARI, UKM or financial support in terms of the scholarship received by the first author from program MyBrain 15 by the Ministry of Higher Education (MoHE).