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# Evaluating Spatial Pattern Among Forest Types in Peninsular Malaysia Using FRAGSTATS

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**Abstract:** Forest plays an important role as habitat for flora and fauna. However, due to land use conversion activity conducted by human, the forest area are continually decreasing and facing fragmentation. This study is aimed to evaluate the spatial patterns and determine the status of fragmentation among three major forest types in Peninsular Malaysia namely inland forest, mangrove forest and peat swamps forest. The input data required are forest cover was generated from Landsat-8 imagery acquired throughout year 2016. The input data then was evaluated using an open source spatial statistical package software called FRAGSTATS. Ten landscape metrics consist of percentage land cover, number of patches, patch density, largest patch index, mean patch size, edge density, mean shape index, mean core index, mean nearest-neighbor distance and interspersion and Juxtaposition index were generated using FRAGSTATS. From the result obtained, we found that inland forest encounter the least fragmentation, followed by peat swamps forest and mangroves forest.

**Key words***:* spatial patterns, forest, FRAGSTATS, fragmentation

## 1. Introduction

Forest is a natural habitat for wildlife species that provide space to occupy, move around, survive and coop with extreme climate (Morrison, 2006). Forest also provides their needs such as source of forage, water, reproduction, protection from predators and competitors. Certain wildlife required certain adequate habitat area. For instance, big mammals such as elephants use forest as corridors to migrate to another larger patches habitat on the same forest mosaic area or also called forest patch when the food

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supply at the present habitat which is much smaller patches become scarce. However, conversion from forest to another land use had caused forest fragmentation.

As a result, large forest patches were continuously dividing creating smaller patches and become apart to each other. The deterioration of forest patch size are related directly to poor density of mammal (Matthiae & Stearns, 1981). A study conducted in Peninsular Malaysia (Ruth, 2000) strengthen the facts that mammal in Peninsular in Malaysia also influenced by the trend of patch size. The study showed that the reduction of mammal population are apparent when the size of the natural forest between 6,551 ha to 10,000 ha. When the forest size ≤459 ha is considered, the study discovered that a sharp loss of mammal population on forest patches range from 70 ha to 164 ha.

Thus, this study aims to study the pattern of forest patches in main body of Peninsular Malaysia which can be used to give information and describe the quality of mammal's habitat using free source spatial data of Landsat satellites imagery. FRAGSTATS software is an open source software developed by McGarigal (2012) used in this study have a wide variety of spatial measurement metrics and can measure at patch, class and/or landscape level depends on requirement of the study. For this study, we had choosen ten landscape metrics at class level consist of (1) percentage land cover, (2) number of patches, (3) patch density, (4) largest patch index, (5) mean patch size, (6) edge density, (7) mean shape index, (8) mean core index, (9) mean nearest-neighbor distance and (10) interspersion and Juxtaposition index.

## 2. Methodology

### 2.1 Study Area

The study cover the forest area at the main Peninsular Malaysia body. All area apart from the main body including small island mostly located at Johor, Pahang and Terengganu and significant island such as Pulau Langkawi, a part of Pulau Pinang (at island part), Pulau Pangkor, Pulau Kukup and Pulau Tioman were excluded as the flora and fauna in this area cannot disseminate innately to main Peninsular body, thus we considered not effecting the habitat of flora and fauna at main Peninsular body. Furthermore, the forest located apart from the main Peninsular body only cover small portion (1.16%) from the total forest area of Peninsular Malaysia and it also contain a big number of small size of forest patch that could signinificantly affecting to overall spatial statistic.

The forest area in Peninsular considered in this study were divided into three major forest type; inland forest, mangroves forest and peat swamps forest. We also removed any forest patch area that less than 0.5

hectares (ha) as forest is defines as land more than 0.5 ha with tree crown cover of more than 10 % and the tree should able to reach minimum height of 5 m (FAO, 1998).

## 2.2 Image Processing

A lot of Landsat-8 image scenes of year 2016 were downloaded to cover the whole area of Peninsular Malaysia from USGS Earth Explorer website https://earthexplorer.usgs.gov/. The raw satellite images were go through a few common pre-processing such as radiometric and geometric correction. Then, the spatial resolution of images were enhanced from 30 meter to 15 meter using Gram-Schmidt Pan Sharpening model in ENVI Version 5.3 software.

Instead of using manual digitizing technique or classification techniques (eg: supervised or unsupervised classification), this land cover were segmented using Feature Extraction tool in ENVI version 5.3 software.

From the classification, non-forested area covered the largest area of major Peninsular body (56%), followed by inland forest (including stateland forest, national park and wildlife park), peat swamp and mangroves (41%, 2% and 1% respectively) as shown in statistic chart below. The non-forested area however were excluded in the analysis.

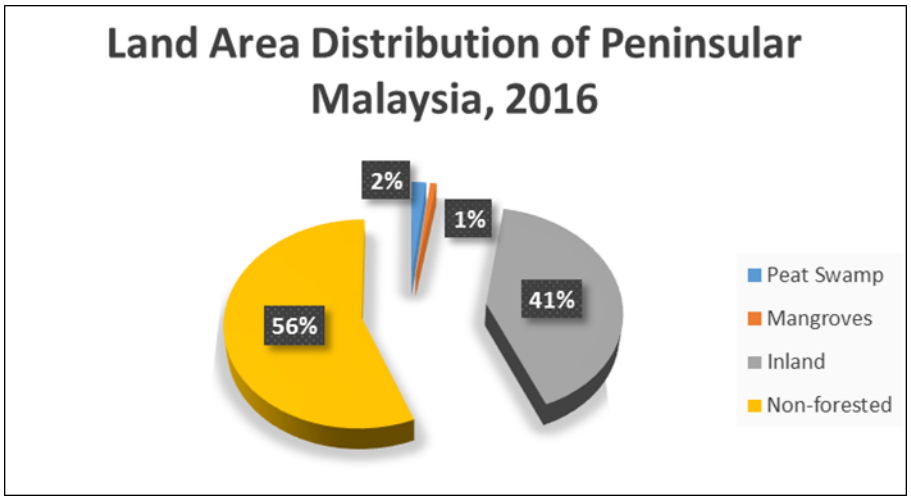


Figure 1: Land distribution of Peninsular Malaysia, 2016

The forest cover input then were converted to gridded raster format of 16 Bit and signed integer. Three tables required by the FRAGSTATS; class descriptors, edge depth and edge contrast also been prepared.

Then, this raster forest cover were run in FRAGSTATS software at class level metric to produce ten metrics related to spatial pattern analysis.

## 2.3 Landscape Metrics

For this analysis, we use ten spatial pattern metrics at class level that have proven useful to analyze the spatial pattern of forest land cover in Peninsular Malaysia namely percentage land cover, number of patches, patch density, largest patch index, mean patch size, edge density, mean shape index, mean core area, mean nearest neighbor distance, interspersion and Juxtaposition index. The descriptions of the spatial patterns used in this study were provided below.

Table 1: Descriptions of spatial pattern metrics

| No | Metrics | Abbreviation | Descriptions | Units |
|---|---|---|---|---|
| 1 | Percentage land cover | PLAND | Percentage of area occupied by corresponding forest type per total forest area of landscape | % |
| 2 | Number of patches | NP | Total number of patches of corresponding forest type | Integer |
| 3 | Patch density | PD | Number of patches of corresponding forest type divided by total forest area, multiplied by 100 ha. Higher PD indicate higher patches number in a given forest area | Number per 100 hectares |
| 4 | Largest-patch index | LPI | Area of the largest patch in each forest type, expressed as a percentage of total forest area. Higher LPI indicates higher species diversity of flora and fauna on that largest patch of correspond forest type | % |
| 5 | Mean Patch Size | MPS | Average patch size of the corresponding forest type. Smaller MPS indicate more fragmentation. | ha |
| 6 | Edge Density | ED | Total of the lengths (m) of all edge segments of the corresponding forest type divided by total area (ha). | m/ha |
| 7 | Mean Shape Index | MSI | Sum of the patch perimeter (m) divided by the square root of patch area ($m^2$) for each patch of the corresponding forest type, adjusted by a constant for square standard (raster). Also in short, MSI is called the average complexity of patch shape of the corresponding forest type. The index will give value 1 for square patch and increase if the patch becomes increasingly non-square shape or also assumed as more geometrical complex shape. Thus, higher MSI value indicate more geometrical complex of forest patch. | None |
| 8 | Mean Core Area | MCA | The sum of the proportion of each patch that is core area ($m^2$) divided by the number of the patches of the corresponding forest type. Lower the MCA value, higher the fragmentation. | ha |
| 9 | Mean Nearest – Neighbor Distance | MNN | Sum of the distance (m) to the nearest neighboring patch of the same type, based on nearest edge-to-edge distance, for each patch of the corresponding forest type, divided by the number of patches of the same type. Lower MNN mean smaller the patches and more isolated the patch from another | m |
| 10 | Interspersion and Juxtaposition Index | IJI | The observed interspersion over the maximum possible interspersion for the given number of forest type. | % |

Source: McGarigal, 2005

# 3. Results and Discussion

## 3.1 FRAGSTATS Metrics

FRAGSTATS can evaluate the spatial pattern at three different level; patch, class and/or landscape level. At patch level, FRAGSTATS give metrics for each patch of every forest types. This information is very detailed and useful, however it is difficult to evaluate as we have 1,721 patches from three forest class (inland forest = 951 patches, mangroves forest = 573 patches and peat swamp forest = 197 patches).

For this study, we see that metrics at class level; which is at forest types class is useful and interpretable to give information about fragmentation status and the quality of forest patches for mammal's habitat. Meanwhile landscape level summarize the metrics by only giving one value for each metrics thus many important information cannot be describe. Therefore, we use spatial metrics at class level for this study. The spatial analysis result obtained from three major forest types are shown in Figure 2.

Table 2: Spatial analysis results generated from FRAGSTATS for major forest types in main body of Peninsular Malaysia

| No | Metrics | Inland | Mangroves | Peat swamps |
|---|---|---|---|---|
| 1 | PLAND | 93.8 | 1.2 | 5.0 |
| 2 | NP | 951 | 573 | 197 |
| 3 | PD | 0.0185 | 0.0086 | 0.0035 |
| 4 | LPI | 57.5 | 0.1 | 2.2 |
| 5 | MPS | 5,062.17 | 146.15 | 1,405.484 |
| 6 | ED | 0.0949 | 0.0046 | 0.0936 |
| 7 | MSI | 1.63 | 1.87 | 1.71 |
| 8 | MCA | 4931.90 | 131.45 | 830.90 |
| 9 | MNN | 648.00 | 488.13 | 663.27 |
| 10 | IJI | 20.23 | 93.70 | 12.73 |

From the forest cover map produced in Figure 2, we can see that the major forest types is inland, followed by peat swamps and mangroves. PLAND metric explained the area allocation in detail and concisely, where inland forest covered 93% from total forest area, followed by peat swamps forest and mangroves forest (5.0%

and 1.2%% respectively).

Inland forest also having highest NP, with value 951 patches. Meanwhile mangroves forest have 573 patches even though its PLAND value is smaller than peat swamp forest. This indicate that mangroves forest is more fragmented compared to peat swamps forest.

PD follow the same trend to NP. PD indicate how many patches (NP) in given area. Inland having highest PD, followed by mangroves and peat swamps with value 0.0185, 0.0086 and 0.0035 respectively. Since this PD value is too small and difficult to understand, we convert this value to ratio and the result is 5:2:1 (inland forest : mangroves forest : peat swamps forest). When translated to words, it means that in a given same forest area size, inland forest have 5 patches, mangroves forest have 2 patches and peat swamps forest has only one patch.

The largest forest patch showed by LPI metric is belong to inland forest which is 57% from the total forest area. The largest patch of peat swamp and mangroves is 2.1% and 0.1% respectively. LPI are used as indicator for species diversity. Higher the LPI value indicates wider the habitat for flora and fauna, thus many variant species can be found and the number of population also higher.

Inland forest have highest mean patch size, followed by peat swamps forest and mangroves as shown by MPS metrics with value 5,062.17, 1,405.48 and 146.15 respectively. MPS is a good indicator to compare the size of the patches. From this value, we can conclude that in average, most of inland forest have large patch size, and meanwhile mangroves have smallest patch size. When we relate MPS with NP, it is very clear that mangroves is the most fragmented forest class as it has many patches but in small patch size.

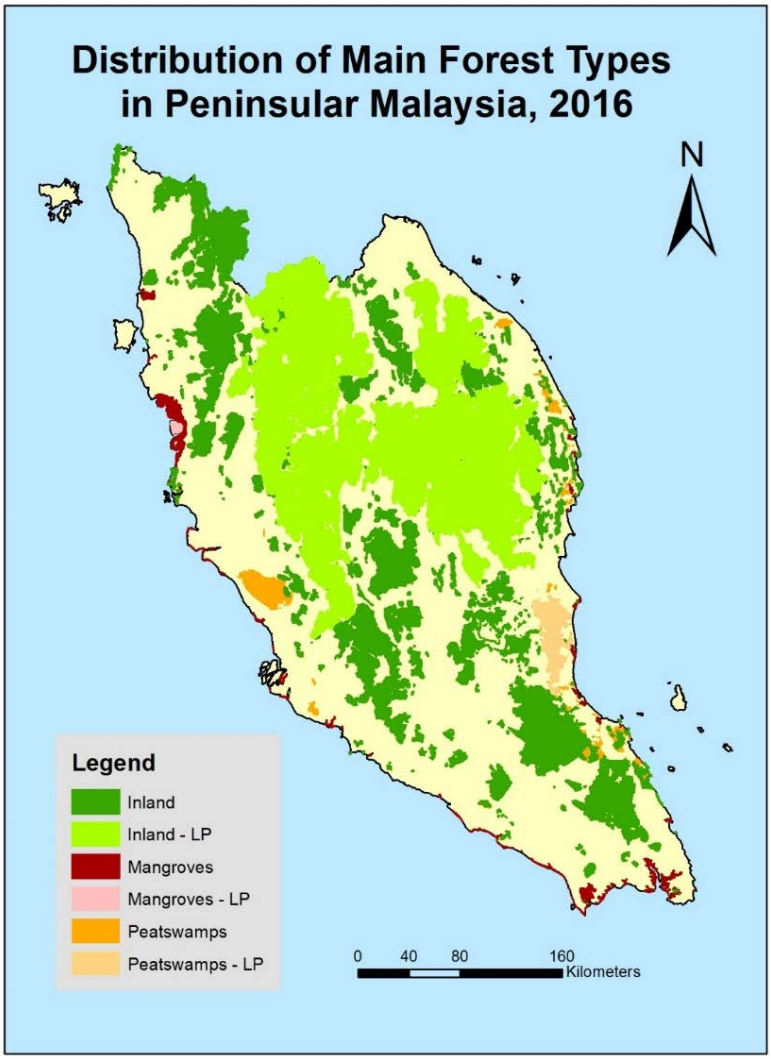


Figure 2: Distribution of main forest types and largest patch (LP) for each forest types in main body of Peninsular Malaysia, 2016

ED is the density of perimeter per hectare area. All forest types have no significant different of ED value. On the other hand, MSI metric give information on the shape of the patches. Higher the MSI value indicate more complex shape of the patches. Mangroves forest have the most complex shape, followed by peat swamps forest and inland forest is the most least complex.

MCA is the sum of the proportion of each patch that is core area divided by the number of the patches of the corresponding forest type. Lower the MCA value indicates higher the fragmentation. The result showed that the MCA value of mangroves forest is the smallest, followed by inland forest and peat

swamps forest.

MNN gives information about the average separation distance to each patch of the same forest class. Lower the MNN value indicate smaller the patches and more isolated the patch from another. The result showed, mangroves forest have lowest MNN value, meanwhile inland forest and peat swamps forest have high MNN value.

IJI explained the distribution of patches of the forest class. IJI value range from zero to 100%. IJI approaches 100% when all the patch of the similar forest class are adjacent to another patch of that corresponding forest patch. The forest patch for mangroves forest are the most clustered, followed by the inland forest and peat swamps forest with value 93.70%, 20.23% and 12.73% respectively.

## 4. Conclusion and Recommendations

The results clearly showed that inland forest in main body of Peninsular Malaysia is the least fragmented, followed by peat swamp forest and mangroves forest. However, the result only covers the spatial characteristics of forest patch. This information cannot be used solely to relate with habitat quality either flora and fauna, as there are many other factors that also influenced the quality of habitat.

Since this study analyze a single time dataset only, we suggest future study to compare the difference of spatial metrics at temporal resolution to see changes of this spatial metrics across the time as the forest at Peninsular Malaysia continuously being converted to another land use for development, plantation, agriculture and other purposes. Therefore, the changes of spatial metrics would give more valuable information about degradation or upgradation of area of any forest types.

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