IOP Conference Series: Earth and Environmental Science

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To cite this article: Amal Najihah Muhamad Nor *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **549** 012006

Impact of land use changes on forest catchment area in Pergau Lake, Kelantan

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Abstract. The Pergau lake basin is a man-made water catchment area comprise of 460 hectares due to the construction of hydroelectric dams in Pergau. It is located about 125 km southwest of Kota Bharu in the Jeli district in Kelantan and managed by Tenaga Nasional Berhad. The lake is rich in natural resources and the forest in the basin acts as a reservoir through water absorption and storage. Forests within the area catchments and basins can control soil erosion and erosion of river banks as well slope collapse is one of the sources of risk floods in terms of damage to property and infrastructure such as bridges and road. However, rapid population growth and urbanisation induced the pressure from human activities have been expanded into the forest catchment area. Therefore this study was conducted in the Pergau Lake (Dam) to safeguard their importance for socio-economic, well-being, ecotourism potential and sustaining its biodiversity. This study aims to predict the land use changes in the study area for 2035, parameterised with satellite images in 1988, 2003 and 2018 and the physical parameter such as slope, road, elevation, distance from built up area, green space edge and waterbody. The integrated approach of remote sensing, Geographical Information System (GIS) and Land Change Modeler-Markov Change Model were used to analyze the changes and their spatial pattern. The results showed that between 1994 and 2004, and between 2004 and 2014 the forest landscape in the Pergau Lake were decreased due to the development of the built-up area. Thus, the results will hopefully take into consideration for land use planning and forest protection for sustainable management planning of the forest catchment area. It is indicated that the spatial effect of green space is influenced by the historical spatial changes, implementation of the previous master planning efforts and uncontrolled land use expansion. This study is designed to provide the novel integrated approach for predicting landscape changes for the forest catchment area to provide the initial guideline for sustainable planning and management of forest catchment area.

IOP Conf. Series: Earth and Environmental Science **549** (2020) 012006 doi:10.1088/1755-1315/549/1/012006

1. Introduction

Nearly 230 million hectares of forest area was lost because of global disruptions with the greatest loss occur in the tropic globally in the period of 2000 and 2012 based on the observance of the data that retrieved from satellite in recent study [1]. Rates of the deforestation were eminent and elevated in South east of Asia. Forest loss in relation to the land area, Malaysia has the highest level compared with Indonesia [2].

For sustainable management of forest ecosystems, the monitoring in the changes of the forest covers and also the understanding of the forest dynamics was important [3]. A serious issue that leads to forest covers disturbances was logging activities and forest fires. The landscape fragmentation and the changes of forests configuration were also increased resulted from deforestation activity despite of the shrinking of forests area.

The landscape fragmentation was defined as the green space or the forest vegetation was break into subordinate unconnected section that occurs due to consequences of land usage such as agricultural activities, construction of roads and development of housing area. Moreover, the forest fragmentation reduced the availability amount of habitat which was also a suite issue followed when the sections of the habitat are not connected [2].

In fact, there are positive and negative impacts of landscape change which depends on the rate of changes, planning, policies, and other factors. However, improper planning towards excessive landscape change will cause lots of negative effect such as the destruction of flora and fauna habitat which contribute to human-wildlife conflicts [4]. The way to measure the landscape changes and identify the landscape fragmentation on green space, the analysis of the landscape fragmentation and its modeling by using the remote sense technique is very significant nowadays. Moreover, this technique is not widely used in Malaysia.

Therefore, the main purpose of this study is to analyse the landscape change and landscape fragmentation in Jeli, Kelantan. Besides that, this study also helps in filling the gaps in the knowledge which is a lack in the using of Geographic Information System and remote sensing in the process of quantifying landscape changes and landscape fragmentation analysis in Jeli area.

2. Methodology

2.1 Study area

Figure 1 shows the map of Jeli which located at the east coast of Peninsular Malaysia. Jeli is located at 5°42′N 101°50′E. The total area of Jeli is 1,330 km². To enter the Jeli district, there are have three entrances which are via Grik which is from the west, via Tanah Merah from east and via Mempelam, Jelawang in Kuala Krai from the south. According to the [5], the total population of Jeli was estimated at 46,700 people which is 2.78% of the total population of the State. Jeli district consists of the high forest coverage area, thus it is chosen as the study area to achieve the objectives of this study which are to quantify the landscape change and to determine landscape fragmentation analysis in 1994, 2004, and 2014.

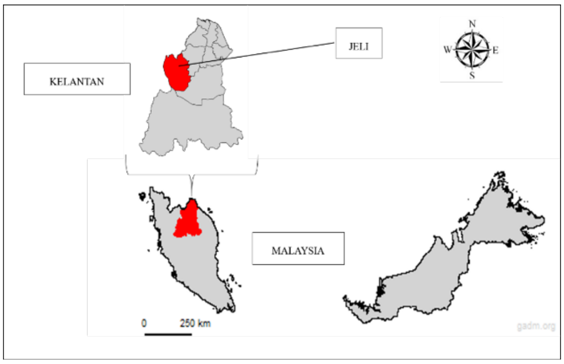

Figure 1. The Map of Study Area

2.2 Research design

This study consists of three (3) phases which are the pre-processing of image, processing of image, and post-processing of image. In data pre-processing, Landsat satellite imagery was used to obtain information about the landscape changes for the study area. Three images of Jeli district were downloaded from United States Geological Survey (USGS) for three respective years which are 1994, 2004 and 2014. The image of 1994, 2004, and 2014 was obtained from the Landsat-4 Thematic Mapper 30-meter image. There was ten years gap between all those three images in 1994, 2004, and 2014.

In data processing, three geocoded satellite images were processed by using ERDAS Imagine 2014 (Intergraph Corporation) and also ArcGIS 10.3 in order to produce LULC maps for Jeli in 1994, 2004, and 2014. The boundaries of the three images that used in this study were obtained from Global Administrative Areas (2018) to extract the area of interest (AOI) from the images. However, the images selected from the satellite of year 1994, 2004, and 2014 were chosen based on the quality of the images according to the coverage of the cloud. The less coverage of the cloud will contribute in the high-resolution imagery which will produce more accurate results when conducting the landscape fragmentation analysis [6].

There were five classes of LULC which were forest, cleared land, agriculture, built up and water body for each year was classified by using supervised classification in ERDAS software. Only land use/land cover types are able to be identified by the ERDAS software because, this classification system is designed to rely mainly on remote sensing [2].

Google Earth was used for reference in the classification process. In order to ensure the validity of the result a field visit was done. This process of field visit to verify the data is known as the ground truthing. Next, in order to check the quality of the classification results, the accuracy assessment was performed in the ERDAS software. This is because the accuracy assessment generated the statistical outputs based on error matrix that compared class-by-class. The samples for each class was validated by using stratified random sampling technique in which 40 samples were assigned for each LULC in steps to avoid uneven distribution [2]. Lastly, the raster data that obtained in the ERDAS software were converted to vector format by using ArcGIS. Finally, the landuse maps of Jeli in 1994, 2004, and 2014 were analysed to study the changes of the landscape and analyse the landscape fragmentation.

In post processing, landscape change analysis and landscape structure analysis were conducted. The amount of forest converted to built-up areas and other land uses between 1994, 2004, and 2014 was determined by using the change detection analysis. Landscape change analysis consists of two steps, the first one was the spatial changes that used to determine the percentage of area for each LULC class for each year. The second step was the transition change which was used to detect the changes of the percentage area between the different class and the same class for that particular year. In order to do the transition changes, the maps from two different years were overlaid in the ArcGIS software and the table containing the conversion of LULC was produced. The overlay was done for 1994 with 2004 and 2004 with 2014. Then, the percentage area in spatial changes and transition changes was calculated manually. The percentages that have been obtained were transformed into graph of transition matric and spatial changes graph.

In landscape structure analysis, the landscape structure of Jeli in 1994, 2004, and 2014 were analysed at landscape, class and patch levels in order to compute the changes in the spatial structures of green space [2]. The entire landscapes were effective to be quantified by the landscape level metrics while the landscape patterns of each LULC were analysed through the class level metrics individually. More specific information about landscape spatial patterns, variations can be provided by the class level metrics at the local level and the distribution of LULC [7]. In understanding the mechanisms of landscape change, patch level metrics are crucial. It was also important in determining significant changes between patches in Land Use/Land Cover class [8].

There were six parameters for landscape structure analysis were choose which were patch density (PD; no. of patches/100 ha), mean patch area (MPA/ha), largest patch index (LPI/%), landscape shape index (LSI;m/ha), Euclidean nearest neighbor distance (MNN/m) and percentage of area (PAREA/%).

The FRAGSTATS software. All of these landscape metrics were used to characterized the changes in green space landscape criteria such as isolation of patches, shape and size.

Next, the statistical analysis was carried out in the SPSS software which was the Analysis of Variance (ANOVA) test was performed. This test was performed in order to compare the significance of the two-landscape metric in analyzing the landscape metric at patch level. Two landscape metrics were chosen are AREA and Euclidean Nearest- Neighbor (ENN).

The AREA and ENN were the landscape metrics that had been chosen to evaluate all the five LULC class in all the three respective years at the patch level which were in 1994, 2004 and 2014. Before the ANOVA test being performed, the normality test was conducted to determine the data distribution was normal or not-normal. Lastly, the landscape transformation process was executed. The image from the landscape transformation were retrieved from the three LULC maps that have been produced in the three years (1994, 2004 and 2014) to shows the landscape transformation process that occurred in Jeli area in those three respective years.

3. Results

3.1 Landscape change analysis

In 1994, the highest percentage of forest area was (65.04%) followed by 2004 (64.47%) and 2014 (62.74%) (Figure 2). The percentage area of built up was smaller compared with the percentage of forest which were in 1994 (4.01%), 2004 (1.60%) and in 2014 was (0.91%). The total percentage of agriculture also increased in 1994, 2004, and 2014 (21.52%, 28.79%, and 30.74%, respectively). The total percentage area of cleared land in 1994 and 2004 was nearly same which have the percentage 4.97% and 4.78%, respectively. Lastly, the water body have the lowest percentage area in 2004 which was only (0.36%), followed by 2014 (1.17%) and the highest was in 1994 (4.45%). Based on the graph it shows that the built-up area was not really cause the impacts towards the decreasing of the forest coverage area but the agricultural areas shows quite high effects towards the forest area decrease. About 32% Ha area in Jeli were represented as the agricultural area [9]. This it still can be said that the anthropogenic activities still give the impacts on landscape fragmentation in Jeli area in 1994, 2004 and 2014.

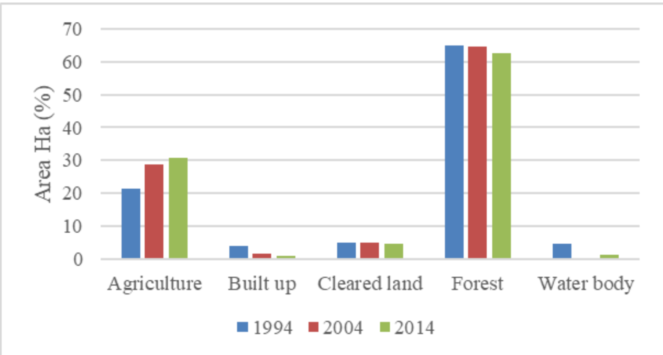

Figure 2. Percentage of area of LULC of Jeli in 1994, 2004, and 2014

The transition analysis shows five types of land use namely forest, water body, cleared land, built up, and agriculture for Jeli area in 1994, 2004, and 2014 (Figure 3). Forest class was the highest contributor of land use in Jeli for both of the transition. In the year 1994 and 2004 the transition of forest with built up was 57.34%. Meanwhile the transition of forest with built up in 2004 and 2014 was 8.87%. Figure 3 shows the transition of built up with forest in 1994 and 2004 was 1.43% while in 2004 and 2014 was 1.48%. The result shows that there was decreasing in transition of the forest with built up in 1994 and 2004 while slightly increasing in the transition of built up with forest in 2004 and 2014.

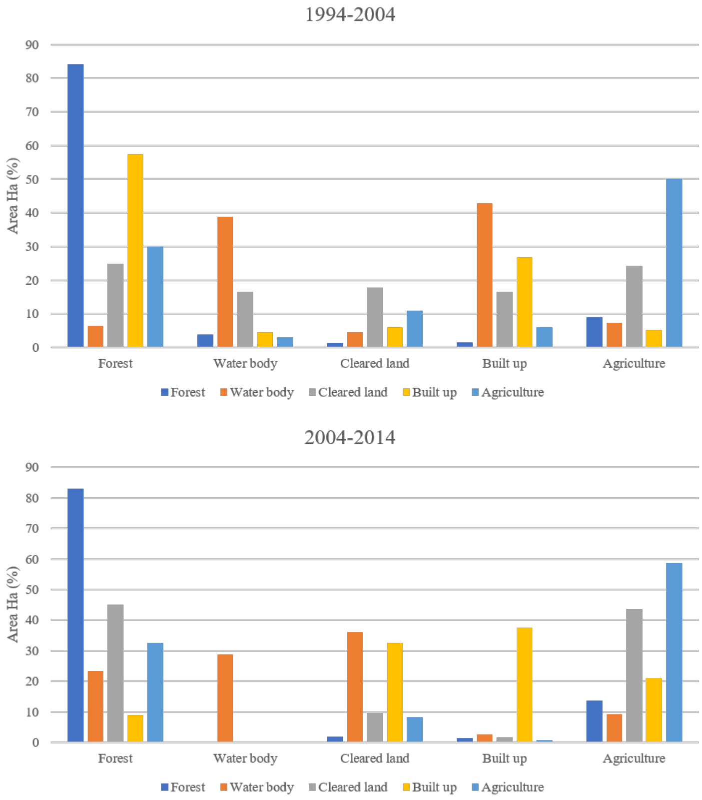

Figure 3. Transition Metric in Jeli Landscape

The transition in 1994 and 2004, for the forest with cleared land shows the percentage increasing in the transition of forest with cleared land in 2004 and 2014 which were from 24.83% to 45.09%. The transition percentage of cleared land was increase due to anthropogenic activities such as deforestation, urbanization, and agriculture. Deforestation was one of the major factors that contribute to landscape fragmentation because it was the major form of habitat destruction [10]. In 1994 and 2004, the percentage of area transition for the forest with agriculture also shows slightly increased in percentage about 2.4% in the percentage of transition in 2004 and 2014. Figure 3 shows the percentage area of cleared land with forest was 1.37% (1994-2004) and 1.78% (2004-2014). There was slightly increased in the percentage of the transition area which was 0.41%.

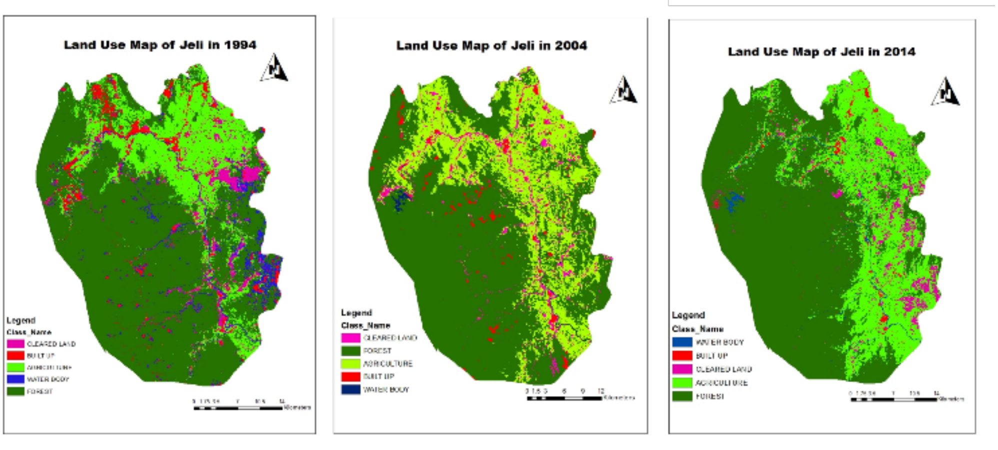

Figure 4. Land use map of Jeli in 1994, 2004, 2014.

Figure 4 shows the LULC maps of the Jeli area in 1994, 2004 and 2014. The maps clearly show the LULC classes that have been increasing or decreasing in the period of the three years with the ten years gap. The map shows that the forest vegetation area has the highest coverage in Jeli. The transition changes results were for supported the maps. It shows the transition areas in 1994 with 2004 and 2004 with 2014. In those three land use maps, the legends and the north arrow acted as the indicator for the future researcher that wanted to refer the land use maps of Jeli in 1994, 2004 and 2014. The dark green color indicates the forest area, red color indicate the built up area, pink color indicate the cleared land areas, dark blue indicate the area of the water body and the light green color shows that the area was covered by the agriculture or crops. The map shows that the forest vegetation area in Jeli was decreasing in that ten years period of gap, and it was due to the anthropogenic activities. The main activity that shows high impacts to the decreasing of forest coverage was the agricultural activities.

3.2 Landscape structure analysis

In landscape structure analysis there were three types of metrics that have been analyzed at class level, which were class, landscape, and patch. There were all six metrics that have been chosen in the comparison of metric at class level which were patch density (PD), Largest Patch Index (LPI), Mean Patch Area (MPA), Landscape Shape Index (LSI), and Euclidean Nearest- Neighbor (MNN). Generally, PD indicates the number of patches per 100 ha. At each class level metric, it shows the number of patches per 100 ha in that particular class while Mean Patch Area or MPA is a function of the number of patches in the class and total class area. According to Figure 5 the PD values for forest decreased from 1.03 to 0.95 patches/ 100 ha in 1994 and 2004. In 2004 and 2014 the PD values of forest was increased from 0.95 to 1.16 patches/ 100 ha. The MPA values for forest shows the increment in year 1994 and 2004 which was from 62.92 increased to 67.25 ha. However, the MPA values then decreased to 54.00 ha in 2014. From all of the three years, it shows that the value of PD was lower than the values of MPA. According to [2] when the PD values was low compared with the high values of MPA, the aggregation of patches was occurred. Aggregation of patches means the degree of clumping of patch types. The dispersion and interspersion of each LULC class also deals with the aggregation metrics [2].

The PD values for built-up in 1994 was decreased from 1.37 to 0.33 and 0.32 patches/ 100 ha in 2004 and 2014. There was an increment in the values of MPA for built up in1994 and 2004 from 2.94 to 4.93 ha. However, the value then decreased into 2.84 ha in 2014. The Largest Patch Index or LPI is an indicator of the dominance of different land cover classes. In 1994 the patch size of the forest was bigger compared in 2004 which was 51.79 %. The patch size of the forest decreased slightly in 2014 to 49.10%. Here the results indicated that the size of forest patch in 1994 was biggest compared with the other two years. This is because of the Jeli was one of the district in Kelantan which still have the high percentage of forest cover which was supported by [9]. It is stated that until 2010, 51% of Jeli was a natural forest cover. Next, the LPI for the built- up was decreased continuously starting from 0.55 %, 0.09% and 0.07% in 1994, 2004 and 2014 respectively.

Landscape Shape Index (LSI) is functioning to measure the overall geometric complexity of class. LSI also can be understand as a measure of landscape disaggregation. The patch types is more dispersed with the higher value of LSI [10]. LSI value of forest for those three years was decreased from 31.36, 30.37 and 23.75 m/ha. However, the LSI value for built-up was decreased to 21.04 m/ha in 2004 from 45.22 m/ha in 1994. In 2014 the LSI value for built-up area slightly increased into 23.61 m/ha.The value of LSI for built-up and forest was decreased which revealed the patches for both of the class was not complex [11].

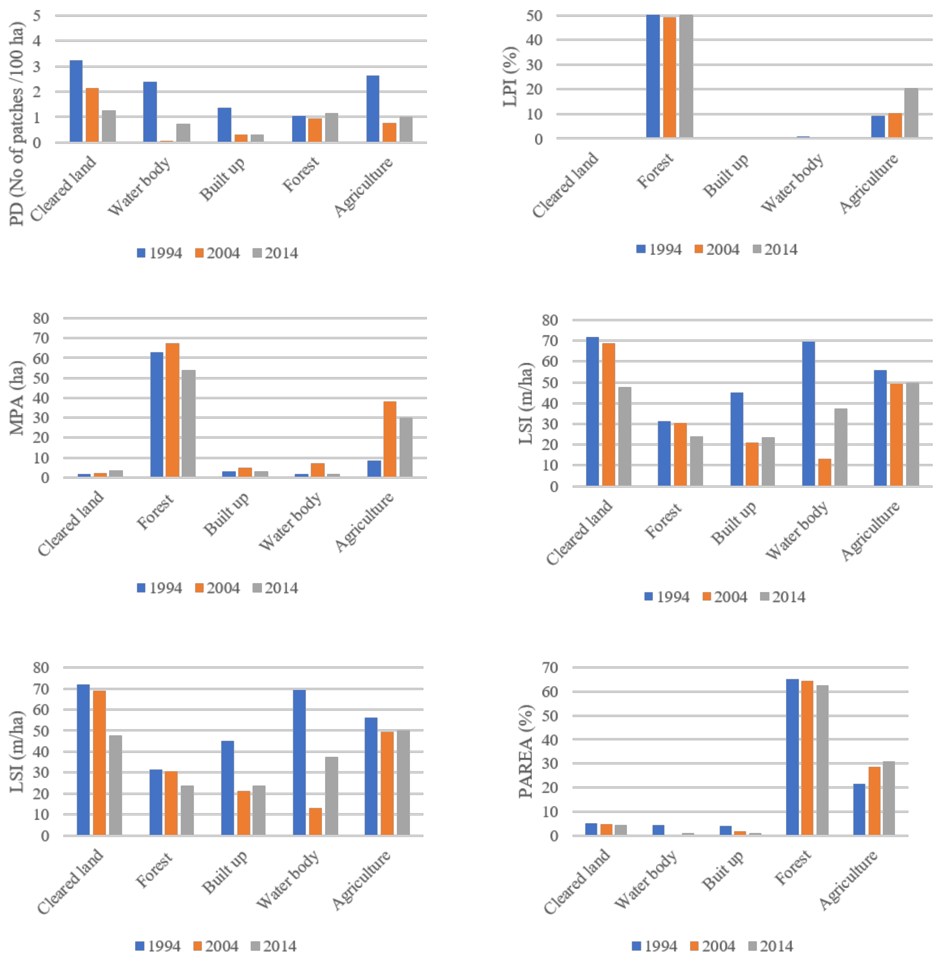

Figure 5. Comparison of Landscape Metric at Class Level

According to [12], ENN or Euclidean Nearest-Neighbor Distance measures the distance between one patch with its nearest neighbor of the same class. In all the three respective years, the distance between forest patches to the neighboring patches increased from 128.08, 152.08 and 154.18 m. From the results, it can be clearly determined the forest patches experienced the shrinkage in landscape fragmentation. Likewise, the ENN value for the buil-up patches in 1994 and 2004 was increased from 204.15 m to 441.02 m. This shows the highest increment in the distance of the built-up patches with its nearest patches. However, the the ENN values in 2004 was decreased to 351.24 m in 2014. Thus, the results can help in urbanization planning and also forest clearing planning in future to prevent the forest patch decreasing over a period of time.

PAREA or also known as the Percentage of area functioning to measure each of patches type in landscape in percent. The results shown that the PAREA of the forest patches was decreased by 1994, 2004, and 2014 which were 65.00%, 64.46% and 62.72% respectively. Likewise, the PAREA of built-up patches were also shows the decreasing trends which were 4.03% in 1994, 1.61% in 2004, and 0.91% in 2014. The decreasing of forest patches percentage may due to all the anthropogenic activities during that particular time at Jeli. While the decreasing of the built-up patches area percentage in 2014 which was only 0.91% was because the urbanization rate at Jeli may have slowdown in that year. This result could give an insight for the state government in order to planning future forest clearing either for economic or for urbanization aspects.

3.3 ANOVA test

The result of ANOVA test between LULC class and AREA, LULC class and ENN of the year 1994, 2004 and 2014 proves that different LULC class has significant different in AREA value and ENN value for year 1994. In the year 2004 and 2014, the different LULC class has not significant influence the AREA value. However, different LULC class has significant influence the ENN value in 2004 and 2014. The values of the ENN were significant for all the three years which indicated that the distance between neighboring patches of the class in those three years was has significant changes.

Acknowledgements

We are thankful for the funding from TNB Sdn. Bhd. Research team for funding and inviting us for short expedition to conduct this survey. We would like to extend our gratitude to all expedition teams for their kind assistance during this expedition and Faculty of Earth Science, Universiti Malaysia Kelantan, for various administrative and logistics support. This research partially supported by short term grant project funded by UKM-YSD Chair in Climate Change (R/YSD/A1304/01684A/002/2019/00608) and (R/YSD/A08.00/00 698A/001/2018/000543) funded by Institut Perubahan Iklim UKM.

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