Monitoring and mapping leaf area index of rubber and oil palm in small watershed area

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Monitoring and mapping leaf area index of rubber and oil palm in small watershed area

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Abstract. Existing conventional methods to determine LAI are tedious and time consuming for implementation in small or large areas. Thus, raster LAI data which are available free were downloaded for 4697.60 km^2 of Sungai Muar watershed area in Johor. The aim of this study is to monitor and map LAI changes of rubber and oil palm throughout the years from 2002 to 2008. Raster datasets of LAI value were obtained from the National Aeronautics and Space Administration (NASA) website of available years from 2002 to year 2008. These data, were mosaicked and subset utilizing ERDAS Imagine 9.2. Next, the LAI raster dataset was multiplied by a scale factor of 0.1 to derive the final LAI value. Afterwards, to determine LAI values of rubber and oil palms, the boundaries of each crop from land cover data of the years 2002, 2006 and 2008 were exploited to overlay with LAI raster dataset. A total of 5000 sample points were generated utilizing the Hawths Tool (extension in ARcGIS 9.2) within these boundaries area and utilized for extracting LAI value of oil palm and rubber. In integration, a wide range of literature review was conducted as a guideline to derive LAI value of oil palm and rubber which range from 0 to 6. The results show, an overall mean LAI value from year 2002 to 2008 as decremented from 4.12 to 2.5 due to land cover transition within these years. In 2002, the mean LAI value of rubber and oil palm is 2.65 and 2.53 respectively. Meanwhile in 2006, the mean LAI value for rubber and oil palm is 2.54 and 2.82 respectively. In 2008, the mean LAI value for both crops is 0.85 for rubber and 1.04 for oil palm. In conclusion, apart from the original function of LAI which is related to the growth and metabolism of vegetation, the changes of LAI values from year 2002 to 2008 also capable to explain the process of land cover changes in a watershed area.

1. The Extraction of Leaf Area Index

Leaf area index (LAI) of the oil palm plantation can be described as the ratio of the total leaflet area of the plantation to the total ground area of that plantation [1]. North part of Sungai Muar watershed 4697.6 km^2 of area was selected as a study area (figure 1). There are three types of data utilized to monitor and mapping LAI value of rubber and oil palm which are:

i. MOD15A2: Level-4 MODIS global Leaf Area Index (LAI)

This data was free downloaded from http://ladsweb.nascom.nasa.gov/data/search.html at1-kilometer resolution on a Sinusoidal grid. The MOD15A2 is composited every 8 days include LAI, FPAR, a quality rating, and standard deviation for each variable. Tiles are 10 degrees by 10 degrees at the equator. There are seven (7) set of LAI data downloaded starting from year 2002 to 2008. All of this data set (year 2002 to 2008) was used to detect general LAI changes. However, only three years of LAI data year 2002, 2006 and 2008 used, to determine LAI value for rubber and oil palm. This is due

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to only these three years of land cover data was available to provide additional information to extract correct LAI value.

Table 1: Characteristic of MOD15A2 data

Temporal Coverage	February 18, 2000
Area	~10 x 10 lat/long
Projection	Sinusoidal
Dimensions	1200 x 1200 rows/columns
Resolution	1 kilometer

Source: https://lpdaac.usgs.gov/products/modis_products_table/mod15a2

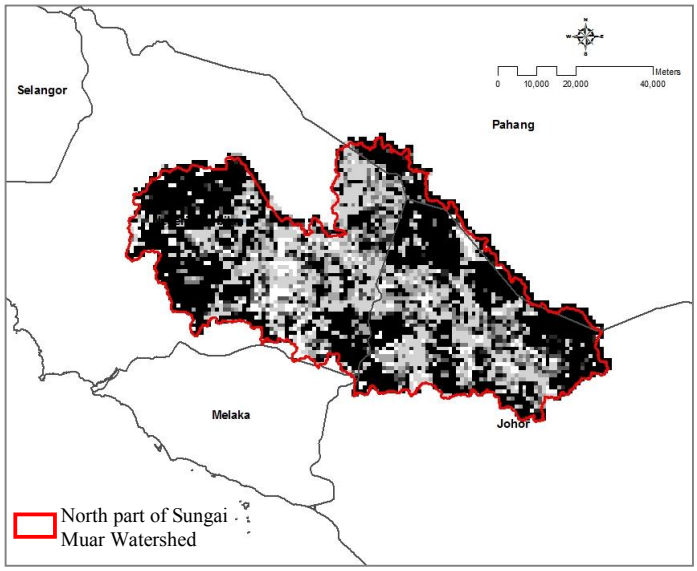

Figure 1. Location of study area.

ii. Land cover data
Digital land cover map; year 2002, 2006 and 2008 was obtained from Department of Agriculture, Malaysia. These maps, which consist of agriculture information, digitized using ArcGIS 9.2 and stored in geodatabase environment. More than thirty types of land cover information consist in the maps. However, only three most dominant land cover were experiencing mass changes from 2002 to 2008, which were forest, rubber and oil palm as shows in figure 2.

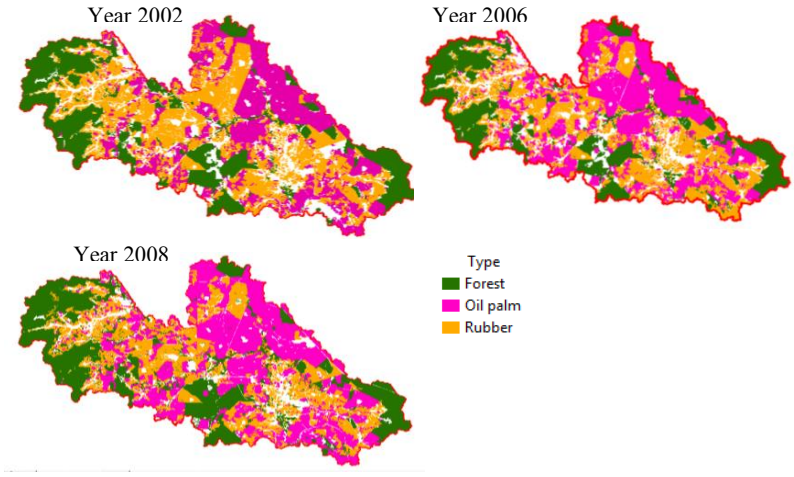

Figure 2. Three years of available land cover data.

Later, land cover boundaries of forest, rubber and oil palm for each year used to generate 5000 sampling points using Hawths Tools in ArcGIS 9.2. These points used to extract LAI value information from MODIS LAI data.

iii. List of LAI's value for rubber and oil palm from previous research were extracted and used to assist the process to determine both crops LAI's range value. All of these reference study conducted empirical study to obtain the LAI's value. Based on table 2, range of LAI's value for rubber is from 0 to 9; and for oil palm is from 0 to 6. Therefore, only these range of value will be consider used; coupled with MODIS LAI data to determine LAI's value for rubber and oil palm.

Table 2. Range of LAI value for rubber and oil palm.

LULC	Age	Literature Value
Oil Palm	5 years	1.71 to 2.19 [2]
	0-4 years	0.67 to 2.39 [3]
	8-9 years	The maximum leaf area index is 4.0 [4]
		LAI can exceed about 6.0 [4]
		3.87 to 4.52 [5]
		3.93 to 5.10 [6]
		3.0 to 6.0 [7]
		2.5 for solitary palm [8]
		Under good conditions a full canopy cover is obtained by the 5-6th year after planting when the leaf area index (LAI) is around 6 [9]
Rubber		3.0 for intermediate canopy [10]
		Mature rubber trees
		The maximum leaf area index is 5.5
	15 years	The optimum LAI mean is 7.223 with an optimum maximum LAI at 8.99

2. Data Processing

There are two processing output produced in this study namely:

(i) General LAI's value changes including mapping from year 2002 to 2008. For this purpose, all available MODIS LAI data for each year utilized.
(ii) LAI's value changes including mapping for rubber and oil palm within year 2002 to 2008.

Before these two processing can be conducted, raw data of MODIS LAI were projected to Rectified Skew Ortomorphic Malaysia (RSO Malaysia) projection in ERDAS Imagine software. Then, these data were subset with the north part of Sungai Muar watershed boundary. Originally, there are 6 layers of MODIS LAI data namely; Fpar_1km, Lai_1km, FparLai_QC, FparExtra_QC, and LaiStdDev_1km. However only layer Lai_1km used to obtained LAI value in the study area. As referred to user guide manual, the Lai_1km layer was multiply with scale factor value 0.1.

$$\text{LAI value} = \text{Lai\_1km layer} \times 0.1 \quad (1)$$

3. Results & Conclusion

Later, these data transferred to ArcGIS 9.3 environment to conduct LAI extraction processing. The 5000 sampling points, which generated earlier, utilized with rubber and oil palm land cover boundaries for year 2002, 2006 and 2008. Therefore, only same years of MODIS LAI data overlay with sampling points and land cover boundary for LAI's value extraction (see figure 3). Next, extracted LAI's values for both crops compared with LAI value deriving from previous research

conducted by numerous researchers. Three types of land cover; forest, oil palm and rubber were compared its LAI's value (see figure 4).

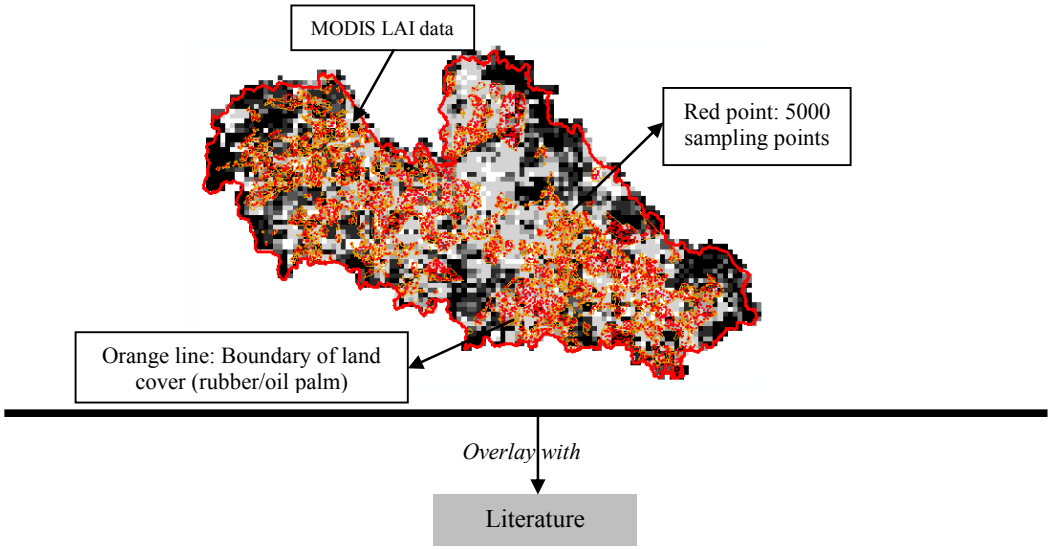

Figure 3. Method of extracting LAI value

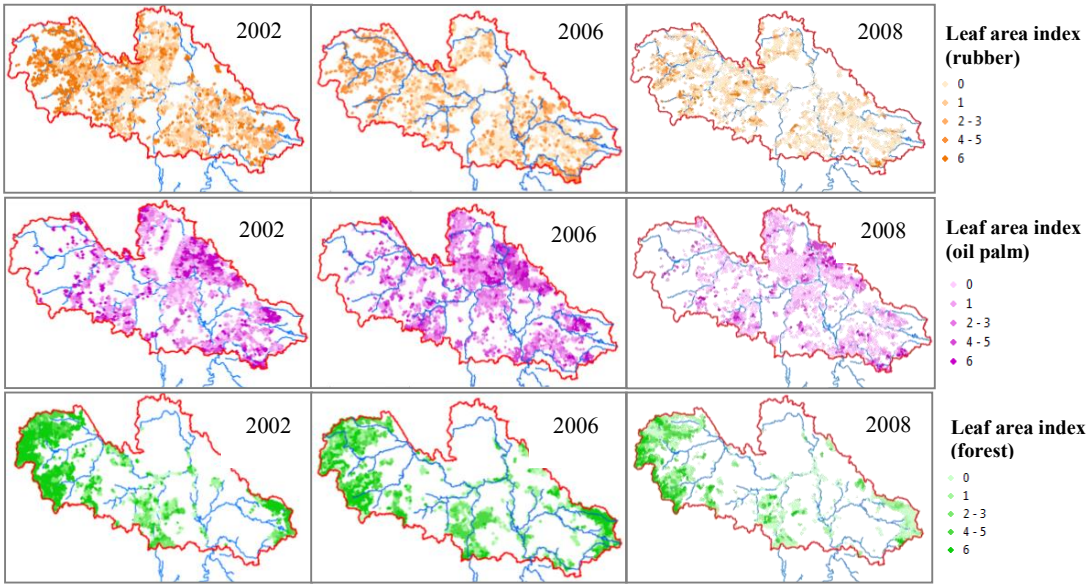

Figure 4. LAI changes for forest, rubber and oil palm.

The mean value for each land cover using three years of data is displayed in figure 5. As a whole, mean LAI's values for the three types of land cover are depleting. Although the mean value of LAI's forest depletes its value is still higher as compared to oil palm and rubber. This has affected the mean of rubber's LAI value during the year, which is lower than oil palm. In 2006, the age of oil palm for the newly planted area is estimated less than 4 years. At the young age of oil palm; its leaf coverage is extremely good and produces higher mean LAI value as compared to rubber. However, mean oil palm's LAI values depleting when it is grow older due palm leaf coverage is poor. Meanwhile, since 2002, forest and rubber area in Muar Watershed depleting due to some area involved in major transition to oil palm cultivation. This factor also influences the declining of LAI's value for both rubber and forest land cover.

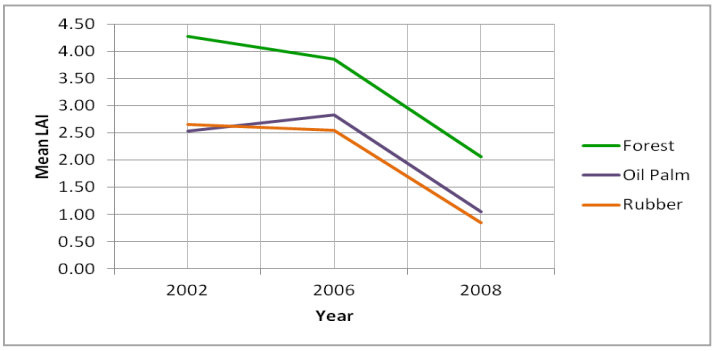

Figure 5. Pattern of leaf area index for rubber, oil palm and forest in Sungai Muar watershed.

Based on the output of this study, it can be summarized that the utilization of MODIS sources for LAI measurement is appropriate for monitoring continues changes of land cover in a watershed. Furthermore, if this information integrated with spatial land cover information and documented cultivation data, we can estimate the age of every land cover and predicting what is happening in a watershed such as hydrologic process.

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