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Application of MODIS Data to A Decadal Study of Fire Hotspots and Climate Relationships Over Riau Province Indonesia

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ABSTRACT— ***Riau is the second most prone burned province in Indonesia. Indofire datasets for Riau province show that peak fire is occurred in both wet and dry seasons every year for ten years. Occurring fire has been related to climate parameters i.e. Southern Oscillation indexes (SOI) and precipitation. Correlation between fire and those two climate parameters is evaluated using cross correlation analysis. The results show that the highest coefficient correlation of fire and precipitation is -0.34 for cross correlation lag +2. While coefficient correlation of fire and SOI is peak on -0.28 for calculation of cross correlation lag +2. This research concludes that in Riau province for a decade evaluation data (2001-2010) both precipitation and SOI best related to the next two months of occurring fire.***

Keywords— Riau province, FHS, precipitation, SOI, cross correlation.

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1. INTRODUCTION

Indonesia has large areas of tropical forests which have significant roles in terms of forestry, natural habitats, Carbon and Oxygen budgets. Fire is considered as an extreme factor affecting degradation of the forest. Forest fire in Indonesia has impact on a regional scale, affecting human health, air traffic navigation, and ecosystem balances.

The Indonesian government manages its concerns in controlling fire occurrence by tasking three agencies (Forestry ministry, Environmental ministry, and LAPAN) as the authorized agencies in fire management and control, fire effect analysis and environment conservation, and fire detection or monitoring research.

In order to support government policy, the FireWatch Indeonesia Project, Indofire has been developed as a collaborative project between Indonesia's Ministry of Forestry, the Institute of Aeronautics and Space, LAPAN, the Ministry of Environment, and the Australian Government through AusAID and the Western Australian Government Department Landgate. Indofire is a fire monitoring system which is aimed at fire detection over the Indonesian region and is used as a base fire detection system for the three authorized agencies. This system provides fire hotspot information from the year 2000 up to the present.

The number of detected fires that occur each year in a particular region show a wide variation [1]. A typical example is the situation of Indonesian fires detected by the Indofire system for ten years from 2001 to 2010 inclusive, shown in Figure 1. The highest FHS number occurred in 2006 followed by peak numbers of FHS in 2009 and 2004, ranked second and third respectively.

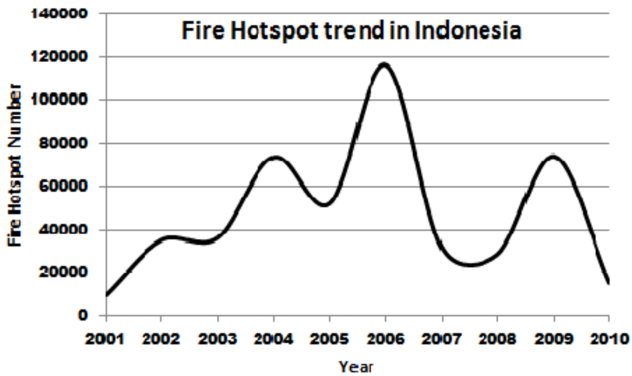


Figure 1. Fire Hotspot trend in Indonesia for one decade.

The El-Nino and Southern Oscillation (ENSO) is a climate cycling phenomena well documented for its impact on weather patterns, in particular in the Pacific region. The Southern Oscillation Index (SOI), defined by the difference between the sea surface pressure level of Tahiti (central Pacific Ocean) and Darwin (west pacific ocean) is a measure of the strength of the ENSO condition. El-Nino is defined as a condition in which SOI values are negative for more than 6 months respectively [2, 3]. The more negative SOI values, the more strength the El-Nino event exhibits. An El-Nino event is also related to drought and fire activity [4, 5]. For example, Wooster, Perry and Zoumas [4] report changed patterns in the FHS diurnal cycle between El-Nino and non El-Nino seasons in Borneo based on a study of a 20 year period. In the El-Nino season (1998) they confirmed that the fire diurnal cycle appears longer while in the non El-Nino season their records show that fires occur predominantly during a short time with a peak in the early afternoon.

The aim of this work is to investigate the temporal patterns in the number of fires over a period of one decade and compare these to climatic factors. In this paper we present temporal trends of fire occurrence in Indonesia for a decade and the relationship to climate parameters, represented in this case by the SOI.

2. RESEARCH METHODS

Three data sets have been obtained to analyse for relationships between FHS and climate variability for the decade from 2001 to 2010; Southern Oscillation Index (SOI), FHS and precipitation. The spatial extent for the study encompasses two regions, Central Kalimantan (Kalteng) province), and Riau province (see Fig. 2). FHS data, based on MODIS data, is obtained from the Indofire system (http://indofire.landgate.wa.gov.au/). The data were extracted to get information for Indonesian provinces on the occurrence of FHS (See Table 1). The two provinces most prone to fires, based on the numbers of FHS detected, were chosen as the research areas. The trends of fire activity of the two provinces are analysed for the decadal period. Additionally, precipitation data in mm was obtained from the Meteorological, Climatology, and Geophysical Agency of Indonesia (BMKG) for Pekanbaru station (capital city in Riau Province). SOI values were accessed from the Australian Government's Bureau of Meteorology website (on the link http://www.bom.gov.au/climate/current/soihtm1.shtml#top.

Time-series data analysis is best application for the data with 50 or more time period datasets. This analysis is best to use for data with autocorrelation. Time series data analysis is aimed for patterns recognition of sequential data over time. The data is mostly correlated to their selves but might have time offsets. Examining the impact of one or more related parameters which might interfere in the research is another application of time series data analysis. Relationship of those data is performed using cross correlation analysis.

Figure 2. Riau and Central Kalimantan (Kalteng) provinces location

3. RESULTS AND DISCUSSIONS

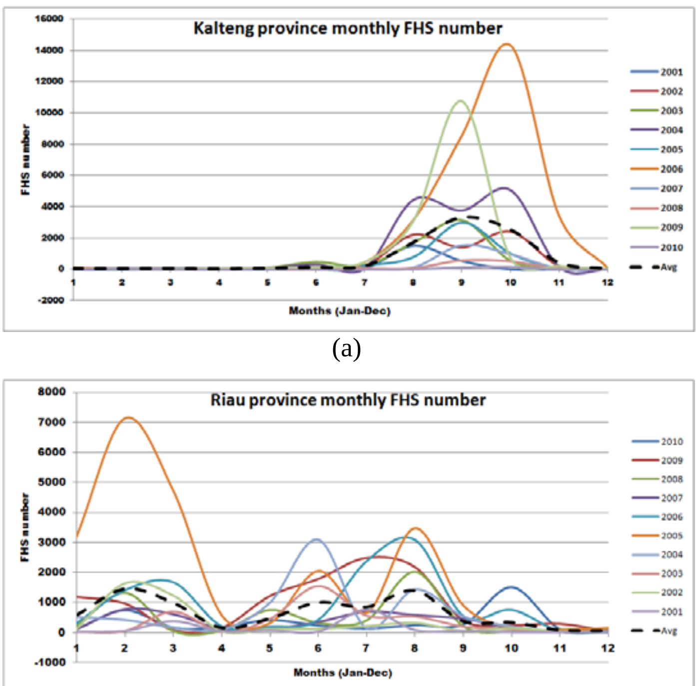
A simple analysis of fire trends in Indonesia for a decade by province shows that the highest ranked province by FHS is Central Kalimantan, followed secondly by Riau province (Table 1). The locations of both provinces are shown in Figure 2 on the map of Indonesia.

Table 1. Average FHS number in Indonesia for 2001-2010

No	Provinces	FHS number		No	Provinces	FHS number
1	Central Kalimantan	8482		18	West Jawa	617
2	Riau	7604		19	Bangka-Belitung	523
3	West Kalimantan	5180		20	Aceh	477
4	South Sumatera	4429		21	North Maluku	437
5	East Nusa Tenggara	2669		22	Maluku	419

6	East Kalimantan	2349		23	Central Jawa	299
7	Papua	2162		24	Bengkulu	280
8	South Kalimantan	1897		25	North Sulawesi	215
9	Jambi	1756		26	West Sulawesi	186
10	North Sumatera	1372		27	Gorontalo	173
11	South East Sulawesi	1037		28	Islands Riau	169
12	South Sulawesi	871		29	Banten	123
13	East Jawa	799		30	West Irian Jaya	111
14	Lampung	774		31	DI Yogyakarta	37
15	Central Sulawesi	690		32	Bali	11
16	West Nusa Tenggara	679		33	DKI Jakarta	10
17	West Sumatera	623				

All FHS data were aggregated by month for the decadal period. Total FHS by month of year are plotted in Figure 3 for each year. The annual FHS curves show that Riau has more than one peak fire seasons in a year compared to the FHS pattern for Central Kalimantan (Kalteng) province (Figure 3) which shows the majority of fires occurring in a single short period from around August to November.



(b)

Figure 3. Monthly fire curves for (a) Central Kalimantan and (b) Riau province

The extracted FHS in Riau province on day and night time separately for ten years time series data as shown in figure 4 confirms the same phenomena as Wooster, Perry, and Zoumas [4] found.

Linearity between both data series as described by the coefficient of determination is 0.8463 which means that most of FHS in day and night time are highly linearly correlated, but it is clear that there are more daytime fires detected than night time fires.

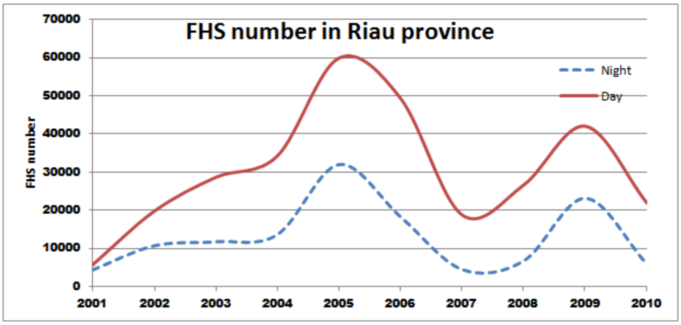


Figure 4. Fire trend occurred in day and night time for Riau province in 2001-2010

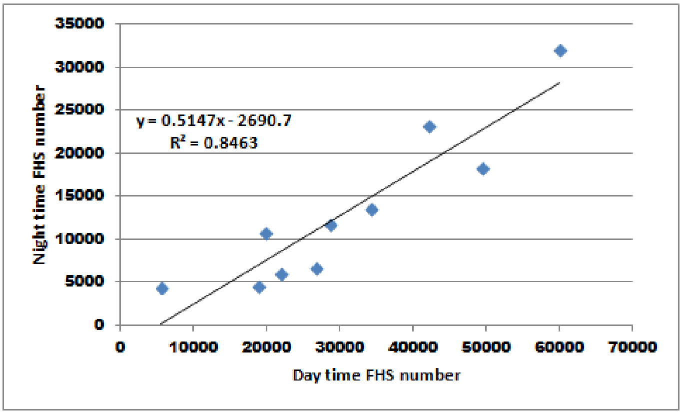


Figure 5. Indofire FHS number of day time and night time relationship in Riau province

The occurrence of fire in the day time is consistently higher than it is in night time, as shown in Figure 4. This might be explained by day time average temperatures being higher than night time, and also, most human activities which may have the potential to initiate fire are carried out during day time. The duration of fires has not been investigated fully. Some day time initiated fires may continue to burn into the night but some may be extinguished prior to nightfall.. Each data point in Figure 5 represents the fire count for the same date for both day and night satellite overpasses.

Other parameters which may have an effect on the temporal distribution of FHS are climate variables such as precipitation and SOI, as reported by [1, 6]. This research investigates how fire activity is related to climate parameters in the Riau province. Fire count (FHS) of time series data for ten years (2001-2010) is correlated to SOI and precipitation without time lag and also for shifted data (lag+1 up to lag +4 months) using cross correlation analysis. It is found that both precipitation level and ENSO index (SOI) have peak values for the coefficient of determination for a lag of +2, which suggests the probability of fires, or the number of fires responds to changes in precipitation with a lag of two months. For example SOI and precipitation on January will affect fire activity in March. Table 2 lists the coefficients for lags from 0 to 4 months. A Negative sign in their values indicates that increasing SOI and precipitation causes a reduction in the fire incidence in the Riau province.

Table 2. Coefficient relationship between fire activity (FHS) and climate parameters (precipitation and SOI)

No	Parameters	Coefficient correlation
1	FHS	1
2	SOI lag 0	-0.23592
3	SOI lag +1	-0.22398
4	SOI lag +2	-0.27813
5	SOI lag +3	-0.18517
6	SOI lag +4	-0.13837
7	Rain lag 0	-0.17017
8	Rain lag +1	-0.26017
9	Rain lag +2	-0.33579
10	Rain lag +3	-0.2811
11	Rain lag +4	-0.19946

4. CONCLUSSIONS

Biomass burning occurs every year in Indonesia with the majority of fire events occurring in central Kalimantan and Riau provinces, ranked first and second respectively in terms of FHS detected. Fire frequency of occurrence peaks in the dry season (Aug-Oct) in Central Kalimantan province but it has a bimodal peak with increased frequency in both dry and wet seasons in Riau province. Day and night time FHS observations do not appear to affect the interpretation of fire activity as they have the same pattern of characteristic, but the number of FHS detected during the day tends to be larger than those detected during the night. In addition, precipitation and SOI have the closest correlation in cross correlation analysis with a lag of +2 with fire activity. Coefficients of determination are -0.28 for fire and SOI and -0.34 for fire and precipitation.

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