Forest Fire Occurrence Analysis Base on Land Brightness Temperature using Landsat Data (Study Area: Jalan Kuantan – Pekan, Pahang, Malaysia)

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Abstract— Forest fire has become huge disaster every year, regardless of their causes, be it human activity or nature. While it is difficult to control nature, it is possible to minimizing fire hazards and avoid potential damage by utilizing remote sensing as one prevention step. Remote sensing plays an important role for detecting and mapping forest fires by digitally and minimize cost. This process used Landsat satellite image and integrated with geographic information layer to derive Brightness Temperature. Brightness Temperature were analyzed three observations the data for forest fire for before, during, and after forest fire occur. This study about the forest fire incident occur in year 2014 that located at Jalan Kuantan – Pekan, Kuantan District of Pahang, Malaysia. The result shows the classification of level fire hazard in the study area and also show the transformation of temperature between pre-fire to post-fire.

Keywords—forest fire; remote sensing; Landsat, Brightness Temperature

1. INTRODUCTION

Forest fire is a natural phenomenon in many ecosystems across the globe. It is responsible for burning more than 350 million hectares of forest land every year. In Malaysia, 1,232 fires have been reported from 1992 to 1998. In general, it is perceived as a threat that causes economic losses, animal habitat destruction, health hazard, etc. Indeed, forest fire prediction and prevention is crucial [1-3]. How to create model or system that is suitable to Malaysian forest characteristics becomes the biggest question to be solved.

This main objective of this study is to make forest fire occurrence using brightness temperature, then apply on selected study area. Data collection is important step for this research. Generally, data collected by performing *in-situ* data collection that will cost more time and money. In this study, several important data, such land surface temperature, will be derived using remote sensing technique applied on satellite images whilst other data will be collected from United States Geological Survey (USGS). Remote sensing as alternative method will not only reduce cost and time, but also get data in both spatial and temporal domains.

The data derived from Landsat satellite images and other collected data will be imported and integrated into GIS format. This step will produce integrated GIS database which consist of raw data required for the model as an input. The expected final deliverables of this study are mapping forest fire which will be very useful for forest fire monitoring.

2. Study Area

The study area is located in Jalan Kuantan – Pekan in Pahang, Malaysia. It is located between latitude 3°36 to 3°46′N and longitude 103°12 to 103°19′E in the centre of Kuantan and Pekan District. The annual average temperature ranges from 20.5° Celsius(C) to 36° C. Bordering the study area is a peat swamp forests. This area was selected because it faces an annual forest fire problem. The study area was destroyed by a fire around February until April year 1998, 2002, 2005, 2007, 2010, and 2014. Numerous of the news can be read about fire that occurred in Jalan Kuantan – Pekan in Pahang, Malaysia [2, 4-8].

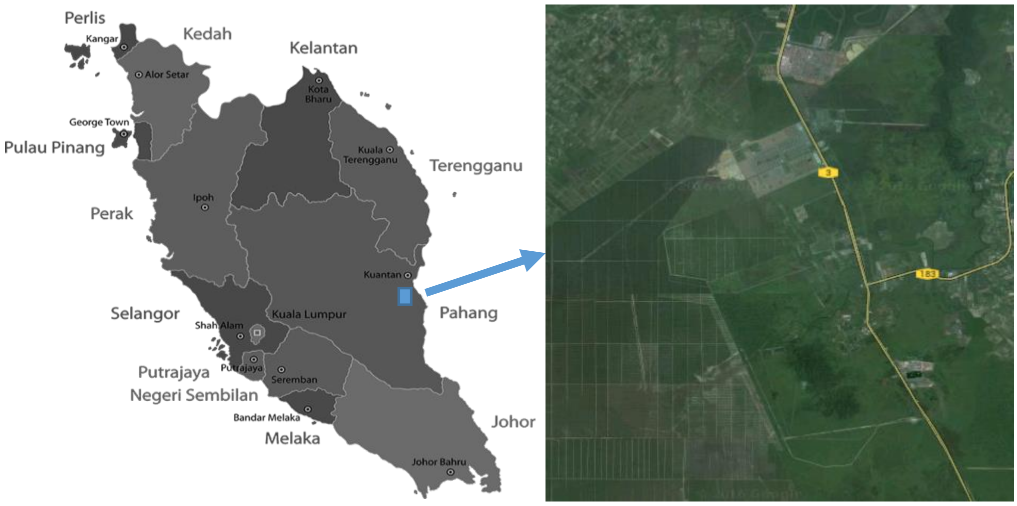


Figure 1: Study Area Region

3. Data and Method

A.Data Processing

Three of the best satellite data from Landsat 8 data was collected between Januarys until March 2014 for the study area. The Landsat data was retrieve from Earth Explorer on United States Geological Survey (USGS) website. The best data was considering less cloud shield within the fire occurred. The study area will use Landsat 8 thermal band 10 cover approximately 226.67km^2 and the classification area will be details in Result. The acquisition dates of the satellite images are shown in Table 1.

Table 1: Image acquisition dates.

Condition	Date of acquisition
Pre- Fire	January 28, 2014
During Fire	March 1, 2014
Post- Fire	March 17, 2014

B.Methodology

The satellite data are collected from USGS that related to this research. The main process for this study are land surface temperature process that will convert from raw data to temperature. Surface brightness temperature process was start by convert the raw data from the thermal band digital number(DN) should convert to radiance(L) [9, 10]. Then, from radiance will convert to Kelvin and lastly convert to Celsius[11]. After complete the surface temperature process, the temperatures are classifying by potential fire hazard level [12]. Result for this study will be mapping to find out the forest fire hotspot in the study area. The methodology is shown in figure 2.

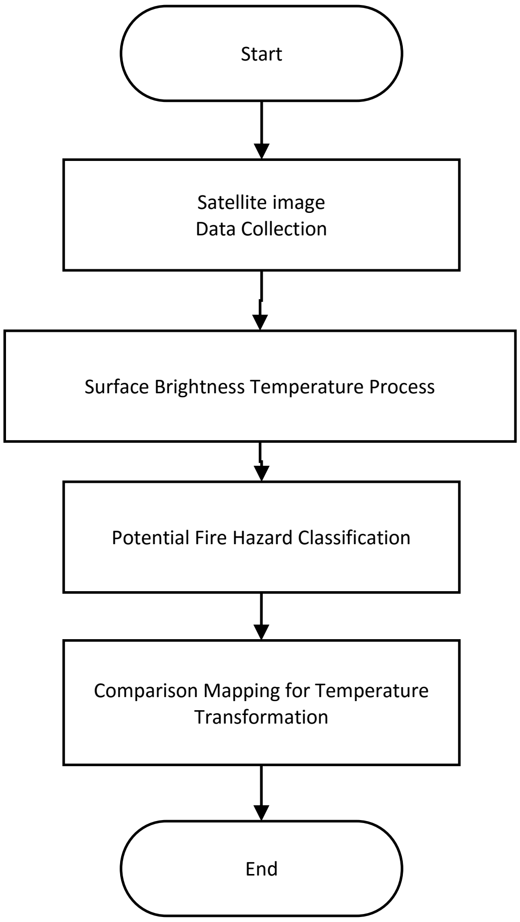


Figure2: Flow Chart of Research Methodology

C. Converting Thermal Band Digital Number (DN) values into Radiance (L)

Equations and parameters to convert calibrated Digital Numbers (DNs) to physical units tabulates the necessary constants for all of the Landsat sensors in one place defined in a consistent manner and provides a brief overview of the radiometric calibration procedure summarizing the current accuracy of the at-sensor spectral radiances obtained after performing these radiometric conversions on standard data products generated by U.S. ground processing systems. Radiometric characterization and calibration is a prerequisite for creating high-quality science data, and consequently, higher-level downstream products [13].

$$L\lambda = \text{"gain"} * QCAL + \text{"bias"} \quad (2)$$

where:

$L\lambda$	= Spectral Radiance at the sensor's aperture in watts/(meter squared * ster * µm)
"gain"	= Rescaled gain (the data product "gain" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * µm)
"bias"	= Rescaled bias (the data product "offset" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * µm)

D. Converting Radiance (L) values into Surface Temperature

Since the USGS launch of Landsat, thermal energy from outside the normal field of view has affected the data collected in thermal Bands. This can vary throughout each scene and depends upon radiance outside the instrument field of view, which users cannot correct in the Landsat Level 1 data product. It is recommended that users refrain from using thermal band data in quantitative analysis in split-window surface temperature retrieval algorithms [14]. The temperature *T* in degrees Celsius (°C) is equal to the temperature *T* in Kelvin (K) minus 273.15.

- Radiance (L) to Kelvin conversion formula:

$$T_{(K)} = K_{(2)} / \ln ((K_{(1)} * E)/L + 1 \quad (3)$$

where:

$T_{(K)}$ = Kinetic surface temperature
K = Constant Value
E = Thermal emissivity (typically 0.95)
L = Radiance band

- Kelvin to Celsius conversion formula:

$$T_{(°C)} = T_{(K)} - 273.15 \quad (4)$$

where:

$T_{(K)}$ = Kinetic surface temperature (Kelvin)
$T_{(°C)}$ = Kinetic surface temperature (Celsius)

4. RESULT

A. Surface Temperature Classification

The surface temperature classification study is to identify and classify the temperature for the study area. There are five category of temperature classification such as Very High, High, Moderate, Low, and Very Low in classify the area using thermal layer of satellite data. ENVI software also has been used for performing and analyzing this thermal layer of satellite data such as Conversion the Digital Number to Radiance, Radiance to Kelvin, Kelvin to Celsius, and lastly classify the temperature classification. The Surface Temperature classification was applied to classify five main areas as mention in above are shown in Figure 4 and the details are shown in Table 5.

Table 5: Total area in square Kilometer cover using surface temperature classification

Temperature Classification (ºC)	**Area (Square Km)**		
	Pre-Fire	**During Fire**	**Post-Fire**
Very Low (< 16)	109.78	0	226.66
Low (16 to 28)	73.05	73.68	0
Moderate (22 to 28)	43.39	84.71	0
High (28 to 34)	0.45	65.81	0
Very High (34 >)	0	2.46	0
Total Area (Square Km)	226.67	226.66	226.66

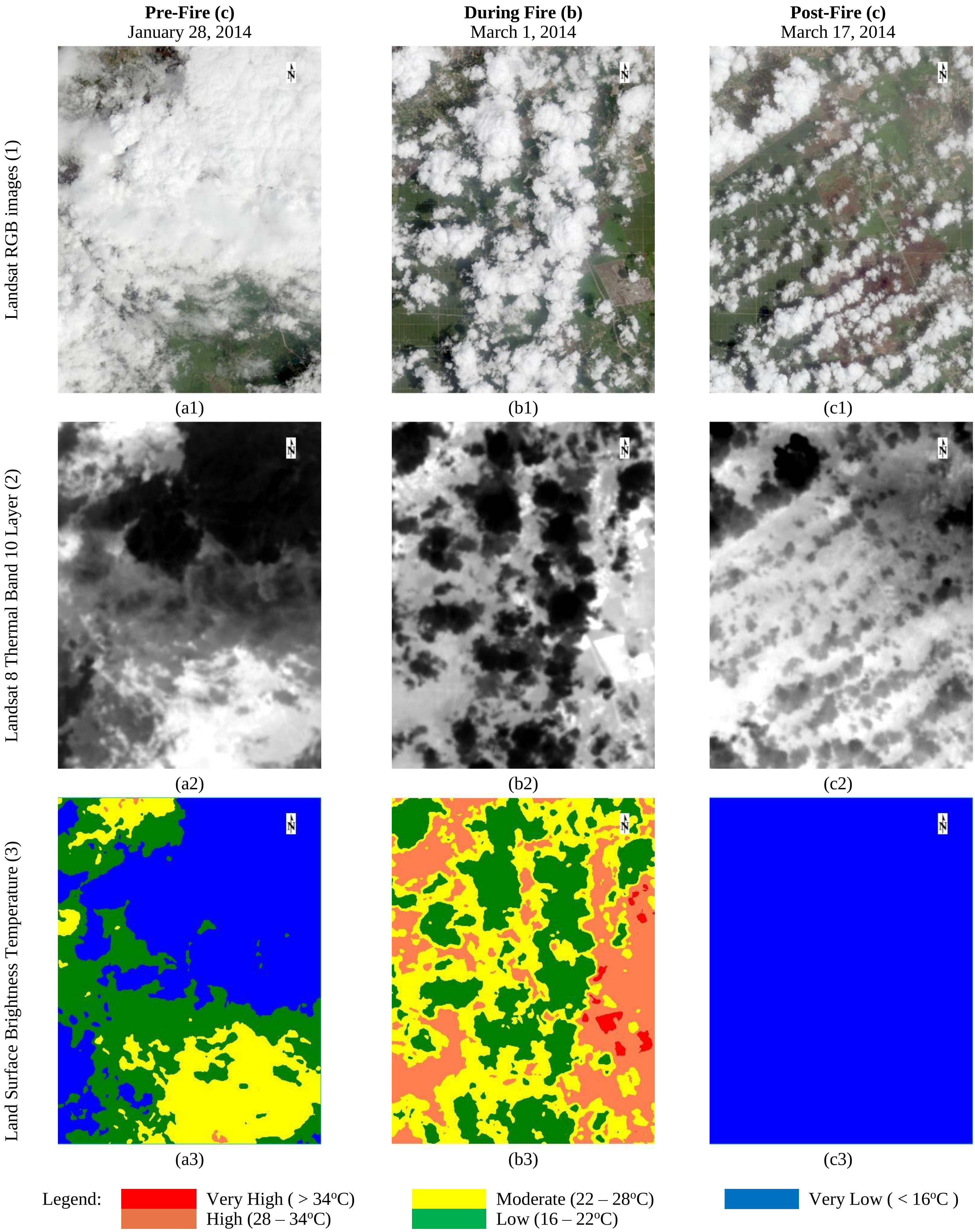


Figure 4: Comparison the study area for Landsat RGB images (1), Landsat 8 Thermal band 10 Layer (2), Surface Brightness Temperature Classification (3), Pre-Fire (a), During Fire (b), and Post-Fire (c)

Figure 4 show the comparison between the acquisition dates of Pre-Fire(a), During Fire(b), and Post Fire(c) base on RGB images(1), Landsat 8 Thermal band 10 layer(2), and Land Surface Brightness Temperature Classification(3). Figure 4(a1, b1, and c1) shows the comparisons of Landsat RGB and the images does no show much changes except the clouds cover area. Landsat RGB only show the actual images from what visible from our eyes and for this study RGB is needed to figure out the actual image at the study time.

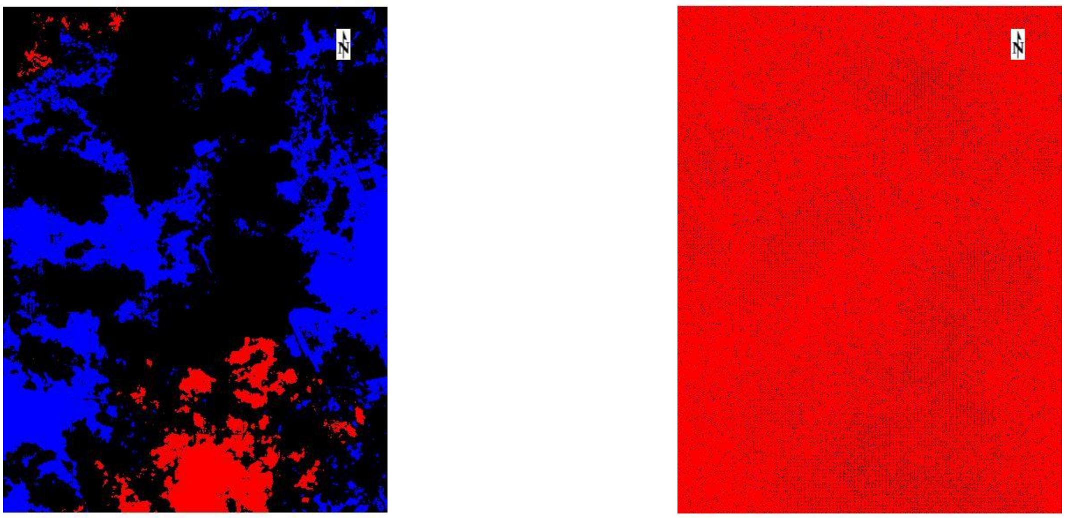
Figure 4 (a2, b2, and c2) show the Landsat Thermal band 10 layer that only consist of digital number and only can view grayscale images. The thickness of the cloud gives some effect to the thermal band 10 layer that thicker the cloud cause lower value of digital number and have darker color using naked eye. Comparing both data RGB and Thermal band data in figure 4 (a1 and a2), (b1 and b2), and (c1 and c2) the relation of brightness temperature and effect by cloud. Brightness temperature from Thermal band 10 need to do some process to retrieve the actual data such as Celsius Temperature. The proses need to do for thermal band are converting from digital number to radiance and radiance to temperature such details in Data and Method above. The result from the process needs to do some classifications and finally the result will be shown in figure 4(a3, b3, and c3) Land Surface Brightness Temperature Classification.

Land Surface Brightness Temperature Classification are divided in to 5 classifications such as Very high (>34ºC), High (20 >= 34ºC), Moderate (22 >= 28ºC), Low(16>=28ºC), and Very Low(<16ºC) temperature. These temperatures have some relationship to cause fire hazard because the higher temperature can lead to fire occur. Surface Brightness Temperature classification for pre-fire near to half of study area are classify as very low temperature is cause of the cloudiness and others area show normal temperature. During fire most of the land area have high temperature such as 2.46km^2 very high classification is cause of the fire happened to the area at the time. The high temperature about 65.81km^2 could be high risk to spread the fire and the low temperature about 73.68km^2 cause by cloud cover. The post-fire shows the most of the area are very low it shows all the fire has been extinguished and not affect by cloud because the cloud only covers 50% of the study area. The further details of the classification are shown in Table 5.

C. Surface Temperature Changes

Our analysis indicates that the study area has undergone the forest fire and related to the transformation or change for several temperatures between pre-fire, during fire, and post fire. Based on our analysis, the study area faced lots of temperature increase between transitions of pre-fire to during fire and temperature decrease for transition form during fire to post-fire. The reviews are shown in Figure 5.

From Pre to During Fire | From During to Post Fire



(a) | (b)

Legend: Temperature Increase | No Change | Temperature Decrease

Figure 5: Change Detection Mapping for Temperature Change between pre-fire to during fire (a) and during fire to post fire (b)

In Table 6 and 7 shows the changes of the temperature between pre-fire to during fire and during fire to post-fire. The pre-fire to during fire shows all of the very low temperature areas have increased the temperature. Around 65 percent of high temperature from the south study area has decrease the temperature to low temperature. On the other hand, 100 percent of temperature decreases from during to post-fire. Table 6 below shows the temperature change from pre-fire to during fire and table 7 shows temperature change from during fire to post fire. The chances from during fire to post fire show the fire occur in during fire 100% goes out.

Table 6: Temperature Change from pre-fire to during fire

Temperature Class (ºC)		Pre-Fire State Percentages (%)					Total
		Very Low *(< 16)*	**Low** *(16 to 28)*	**Moderate** *(22 to 28)*	**High** *(28 to 34)*	**Very High** *(34 >)*	
During Fire State	**Very Low** *(< 16)*	0	0	0	0	0	0
	Low *(16 to 28)*	35.303	30.227	28.939	65.13	0	100
	Moderate *(22 to 28)*	37.013	38.501	36.771	0	0	100
	High *(28 to 34)*	26.996	29.245	33.776	34.87	0	100
	Very High *(34 >)*	0.688	2.027	0.514	0	0	100
Total		100	100	100	100	0	0
Class Changes		-100	69.773	63.229	65.13	0	0

Table 7: Temperature Change from during fire to post-fire

Temperature Class (ºC)		During Fire State Percentages (%)					Total
		Very Low *(< 16)*	**Low** *(16 to 28)*	**Moderate** *(22 to 28)*	**High** *(28 to 34)*	**Very High** *(34 >)*	
Post-fire State	**Very Low** *(< 16)*	0	100	100	100	100	100
	Low *(16 to 28)*	0	0	0	0	0	0
	Moderate *(22 to 28)*	0	0	0	0	0	0
	High *(28 to 34)*	0	0	0	0	0	0
	Very High *(34 >)*	0	0	0	0	0	0
Total		0	100	100	100	100	0
Class Changes		0	-100	-100	-100	-100	0

5. CONCLUSION

This study attempted to mapping the forest fire occurrence using Land Surface Brightness Temperature to identify such study area Jalan Kuantan – Pekan, Kuantan, Pahang Malaysia in year 2014. Remote sensing has the capability of monitoring such changes, extracting the changes information from satellite data. For this research, we have taken Landsat 8 images latitude 3º36 to 3º46′N and longitude 103º12 to 103º19′E from USGS earth explorer website. Temperature Monitoring Change detection analysis shows that lots of area increase the temperature from pre-fire to during fire and 100 percent of temperature decrease form during fire to post-fire. Information on land cover is an opportunity with regards to optimum use important for the selection, planning and implementation involving property use plans to meet up with the actual improving requirements regarding essential human being needs and welfare.

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