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ASSESSMENT FOR THE SEVERITY OF FOREST AREAS BURNT BY FIRE IN THE PHU KRADUENG NATIONAL PARK BY RETRIEVING DATA FROM THE LANDSAT 8 OLI SATELLITE

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ABSTRACT

Forest fire is a problem that has been more and more severe due to the changing climate and other factors caused by humans. This study aimed at developing operation forms that are up-to-date for the analysis of and assessment of the severity of forest fire burnt fire in the Phu Kradueng National Park by retrieving data from the Landsat 8 OLI Satellite. The operation methods are as follows: 1) bring the data from the Landsat 8 OLI Satellite before and after forest fire incident to be adjusted on part of the wave radiation, 2) perform the analysis to find the Normalized Burn Ratio (NBR) and ΔNBR, 3) assess for the severity of forest areas burnt by forest fire in 7 levels, and 4) check for the accuracy of forest areas burnt by forest fire by using the method of visual interpretation into the data obtained from the Landsat 8 OLI Satellite that has passed the False Color Composite process from SWIR - NIR - Red wave ranges (RGB:754); the location was specified by creating 90 random points, dividing into forest area for 30 points, forest area burnt by forest fire for 30 points, and other areas that are not forest for 30 points. After that, consider the overall accuracy and Kappa statistics. It was found from the operation that NBR and ΔNBR can be well used to assess for the severity of the burning, and are consistent with the situations that occur. Also, there is consistency in the accuracy of the burnt forest area from forest fire by the method of visual interpretation.

Keywords: remote sensing, digital image processing, forest fire, burnt severity, normalized burn ratio.

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INTRODUCTION

Forest fire is a fire that happens from the burning of natural fuel such as soil, leaves, branches, and dry leaves and living trees in the forest or urban forest to the extent that it cause the spreading of fire freely and indefinitely. There are 3 elements in combination to cause forest fire including heat, oxygen, and fuel; if any one of such elements does not exist, then the forest fire cannot happen. These three elements are called the "Triangle of Fire" (National Fire Protection Association, 2020). A forest fire can destroy a forest area very rapidly causing the ecological system of the forest to lose its balance, deforming the structure of the forest, decreasing soil nutrients, decreasing the number of wild animals, causing the evacuation of wild animals, damaging food sources, habitat and water sources (Food and Agriculture Organization, 2010). Moreover, forest fire causes smoke and fog which destroy visibility thus being a barrier against land transportation and air transportation; the people living nearby would also be affected, and there might be some accidents, there is air pollution which deteriorates human health considerably. If the forest fire reaches the villages, the residences, properties, and agricultural fields would be destroyed. And the smoke and fog caused by forest fires, which causes air pollution (Cardoso *et al*., 2008), would also lead to the phenomenon called the "greenhouse effect" thus increasing global temperature (Balch *et al*., 2011; Askar *et al*., 2019). In the case of Thailand, the major cause of forest fires is human activities such as the burning of the field, the burning of the forest to look for wild food and to hunt wild animals. Forest fire is considered a serious natural disaster that is often found during the period when the climate is quite dry in Thailand which is November to April of each year (called the season of forest fire). Forest fire is mostly found in the Northern region, followed by the Northeastern region, and the Western region of Thailand. When there is a forest fire happening, the impact is quite strong on the forest's ecological system and against the air quality (Trueplookpanya, 2020). According to the statistics, it points out the forest areas of Thailand which were burnt from 1 October 2018 to 23 July 2019 by the Department of National Parks, Wildlife and Plant Conservation (DNP); it is reported that in the Northeastern region, there had been 1,046 times of forest fire, there had been the burnt area of 37,435,680 m^2. In Loei Province, where the Phu Kradueng National Park is located, it was found that there were 185 times of forest fires, with a total burnt area of 4,900,800 m^2 (Department of National Parks, Wildlife and Plant Conservation, 2019). Looking back during 16-17 February 2020, in the Phu Kradueng National Park which is located in Sri Than Sub-district, Phu Kradueng District, Loei Province, the Northeastern region of Thailand, there had been extreme forest fire which is the strongest in the past 17 years, it was caused by the villagers hunting for wild animals and leaving the fire burning in the forest (Department of National Parks, Wildlife and Plant Conservation; Thailand Forest Fire Statistics, 2019; The Standard, 2020).

Solve the forest fire problem, there are many methods, but not all can be prevented; therefore, the managers and those who are concerned with this kind of work must be well prepared to handle with the forest fire in time and immediately, and must be able to quickly assess for the severity of the forest areas which are burnt by the fire. Currently, there is one field of technology called "remote sensing" which is being used to examine natural disasters including the area where there is forest fire. Such technology makes it possible to obtain data and information rapidly and in time when the fire is happening without having to do the field survey in all actual areas, and the accuracy is acceptable (Zhao and Wang, 2017; Zhao, 2018). Therefore, the application of remote sensing technology by using data obtained from the satellite could save time and expenses spent in the operation (Rotjanakusol & Laosuwan, 2019; Prohmdirek *et al*., 2020; Rotjanakusol & Laosuwan, 2020). Besides, data from the satellite could help identify the location and scope of the areas where the forest fire happens and could help assess the severity of the forest areas being burnt as well (Rotjanakusol & Laosuwan, 2019; Bright *et al.,* 2019; Prasertsri & Littidej, 2020). Consequently, the researcher has become interested in developing a method used to rapidly examine and assess in time the severity of the forest areas burnt by fire, saving time and expenses, and finding ways how to prepare and monitor the forest fire by using advanced technology. For such reasons as mentioned, this study aimed at developing the operation forms that are up-to-date for the analysis of and assessment of the severity of forest fire burnt by fire in the Phu Kradueng National Park by retrieving data from the Landsat 8 OLI Satellite.

STUDY AREA

The Phu Kradueng National Park is located in the Sri Than Sub-district, Phu Kradueng District, Loei Province, Thailand with geographical coordinates of Latitude of 16.56 °N and Longitude of 110.33 °E (Figure-1). It is one of the most famous tourist sites in Thailand. Phu Kradueng was established as the National Reserved Forest in 1943 and became the National Park on 7 October 1959. The Phu Kradueng National Park covers an area of 348.12 km^2, with an altitude between 400 - 1,200 m from the sea level (National Park Thailand, 2020).

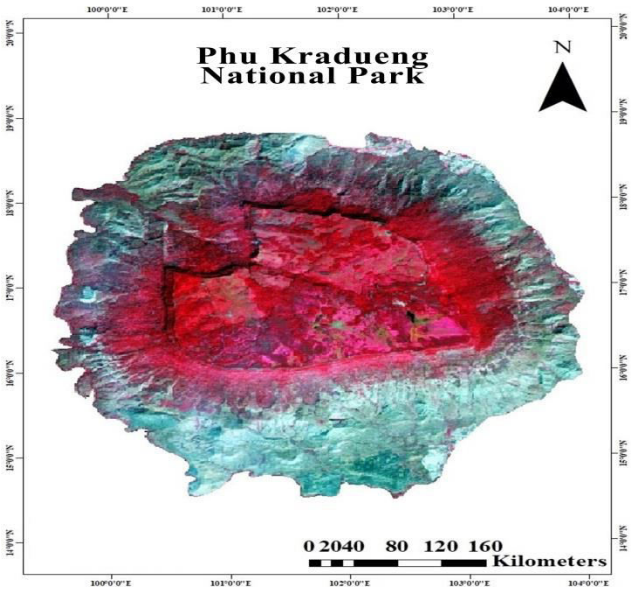

Figure-1. Phu Kradueng National Park.

MATERIALS AND METHODS

Data Collection

Data used in this operation include 1) data from Landsat 8 OLI Satellite (Level-1 data product) path 129 low 048 from EarthExplorer (USGS) for 11 bands during the time before the forest fire happens--data on 27 December 2019 were recorded; and during the time after the forest fire happens--data on 19 February 2020 were recorded (Earthexplorer, 2020). Data from Landsat 8 OLI Satellite contain the spatial resolution of bands 1-7 and 9 of 30 meters, band 8 of 15 meters, and band 10-11 of 100 meters, with spatiotemporal of 16 days, with Map projection of UTM and Datum of WGS84 UTM zone 47, 2) data related to the scope of the Phu Kradueng National Park were retrieved from Department of National Parks, Wildlife and Plant Conservation (DNP) which were in form of shape file, displayed as representative fraction form at 1: 50,000.

Calculation of TOA Spectral Radiance

This is the procedure for converting the DN of data obtained from Landsat 8 OLI Satellite to spectral radiance (L_λ) by Equation 1. After that, calculate TOA planetary reflectance (ρ_λ) by adjusting the angle of the height of the Sun by Equation 1 and Equation 2 (Laosuwan & Uttaruk, 2014; Rotjanakusol & Laosuwan, 2018).

$$L_\lambda = M_L Q_{cal} + A_L \quad (1)$$

Where;

M_L = Radiance Multi Band

A_L = Radiance Add Band

Q_{cal} = Digital Number (DN)

$$\rho_\lambda = M_\rho Q_{cal} + A_\rho \quad (2)$$

Where;

M_ρ = Reflectance Multi Band of Landsat 8 OLI

A_ρ = Reflectance Add Band of Landsat 8 OLI

Q_{cal} = Digital Number (DN)

Analysis of NBR

There are many methods for using spectral indices to study the areas that are burnt. It was found that there were several indices used to analyze and classify the areas which are burnt including Normalized Burn Ratio (NBR), Burned Area Index (BAI), Normalized Difference Vegetation Index (NDVI), and Modified Soil Adjusted Vegetation Index: (MSAVI). According to the study into the documents in recent years, it was found that the indices which are mostly used to analyze the areas being burnt were NBR and BAI. Therefore, in this research, the NBR was chosen as shown in Equation 3 to analyze and divide the forest areas burnt by forest fire (Xiao *et al*., 2019).

$$NBR = \frac{NIR-SWIR}{NIR+SWIR} \quad (3)$$

Where;

NIR = Correspond to the reflectance of band 5 (0.85-0.88 μm) of Landsat 8 OLI

SWIR = Correspond to the reflectance of band 7 (2.11-2.29 μm) of the Landsat 8 OLI

Analysis of ΔNBR

This is to analyze the differential of NBR from Equation 4, to assess for the severity of forest areas being burnt by forest fire by using data obtained from Landsat 8 OLI Satellite during the time before forest fire happens and after the time when forest fire happens. In this study, the severity of forest areas being burnt in the Phu Kradueng National Park is divided into 7 levels. The criteria used to classify the severity are shown in Table-1 (Lasaponara *et al*., 2018).

$$\Delta NBR = NBR_{before\_fire} - NBR_{after\_fire} \quad (4)$$

Where;

ΔNBR = Difference of NBR

NBR_{before_fire} = NBR before the fire

NBR_{after_fire} = NBR after fire

Table-1. ΔNBR value classify for burnt severity.

ΔNBR value	Burnt severity
<-0.25	High post-fire regrowth
-0.25 to -0.1	Low post-fire regrowth
-0.1 to 0.1	Unburnt
0.1 to 0.27	Low-severity burnt
0.27 to 0.44	Moderate- to low-severity burnt
0.44 to 0.66	Moderate- to high-severity burnt
> 0.66	High-severity burnt

Accuracy Assessment

In this procedure, the accuracy of forest areas being burnt is checked due to the reason of reliability of the outcome of the study. In this study, the method of visual interpretation was used by using data from OLI Landsat 8 Satellite that has passed the False Color Composite (FCC) process from SWIR – NIR – Red wave ranges (RGB: 754) (Du *et al*., 2014; Ali *et al*., 2018); the location was specified by creating 90 random points, dividing into forest area for 30 points, forest area burnt by forest fire for 30 points, and other areas that are not forest for 30 points. After that, the overall accuracy and Kappa statistics (Equation 5) were considered. The acceptable number in this study is specified to be the maximum number under the theory is KHAT which must exceed 0.80 (> 80%) (Jensen, 2005). The details of Kappa Statistics are shown in Table-2; that is, the forest areas that pass the analysis by the NBR method must be consistent with the method of visual interpretation at the very-good level only.

Table-2. Strength of agreement of Kappa.

kappa	Strange of agreement
<0	Poor agreement
0.0-0.20	Slight agreement
0.21-0.40	Fair agreement
0.41-0.60	Moderate agreement
0.61-0.80	Substantial agreement
0.81-1.0	Almost perfect agreement

$$KHAT = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} X_{i+} * X_{+i}}{N^2 - \sum_{i=1}^{r} X_{i+} * X_{+i}} \quad (5)$$

Where;

r = Number of rows in the matrix

X_{ii} = Number of observations in row I and column i

X_{i+} and X_{+i} = Marginal totals of row I and column i, Srespectively

N = Total number of observations

RESULTS AND DISCUSSIONS

Result from the Analysis of NBR AND ΔNBR

The analysis results of NBR of data obtained from Landsat 8 OLI Satellite in these 2 periods of time include data on 17 December 2019 (before the forest fire) and on 19 February 2020 (after the forest fire). In this study, it was found that the means of NBR before the forest fire was a minimum at 0.800, with a maximum of 0.980, means equal to 0.950, and a standard deviation of 0.018; for the after forest fire, the minimum was 0.090, the maximum was 0.984, and with means of 0.914 and standard deviation of 0.032. The spatial distributions of NBR of both periods are shown in Figure-2.

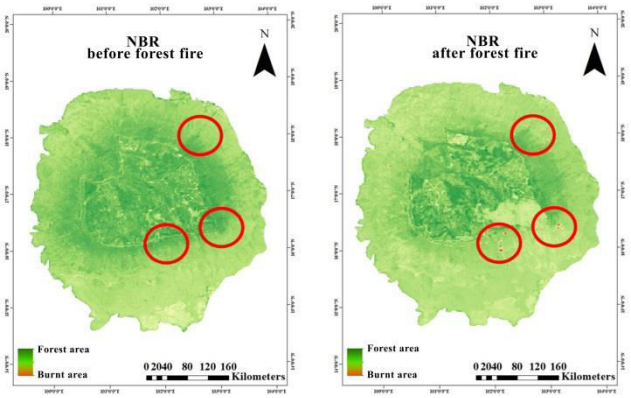

Figure-2. Result of NBR analysis, (left) before forest fire and (right) after forest fire.

From the analysis of ΔNBR on 17 December 2019 and 19 February 2020, it was found that the minimum was -0.143, the maximum was 0.859, the means was 0.024, and the standard deviation was 0.029. The result of the study of ΔNBR shows the forest areas burnt by the fire with a severity of high level; the distribution of ΔNBR is as shown in Figure-3.

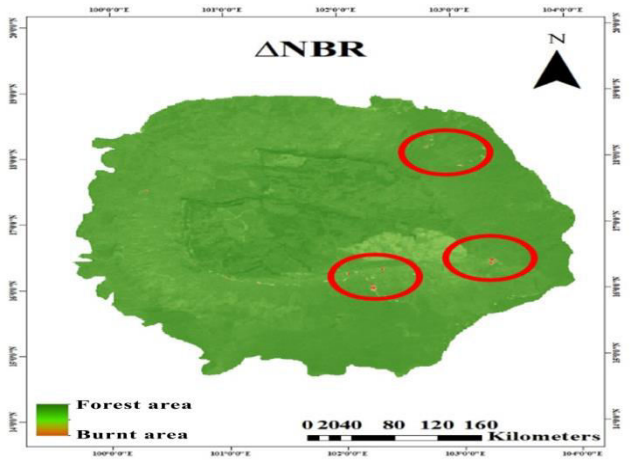

Figure-3. Distribution of ΔNBR.

The Assessment for Severity in Terms of Space

This is the assessment in terms of space or area of the forest burnt by fire. The Phu Kradueng National Park which is located in Sri than Sub-district, Phu Kradueng District, Loei Province, covers an area of 348.12 km^2, with the plain area on the top side of the mountain of 60 km^2. As part of the assessment for the severity of forest area being burnt which is divided into 7 levels of severity, it was found that most areas are at unburnt level, with the areas of such level of 72.84%. All statistics related to the forest areas being burnt under the severity level are shown in Figure-4 and the distribution of severity of the burning is shown in Figure-5.

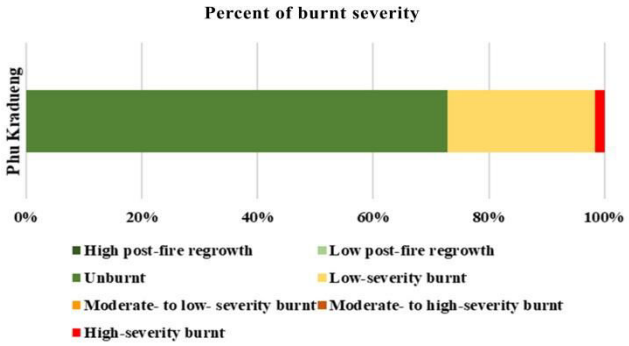

Figure-4. Statistic of the burnt area under the severity level.

When considering the data in the burning group, it was found that the forest areas that are burnt by fire are over 5.56 km^2 (1.6%).

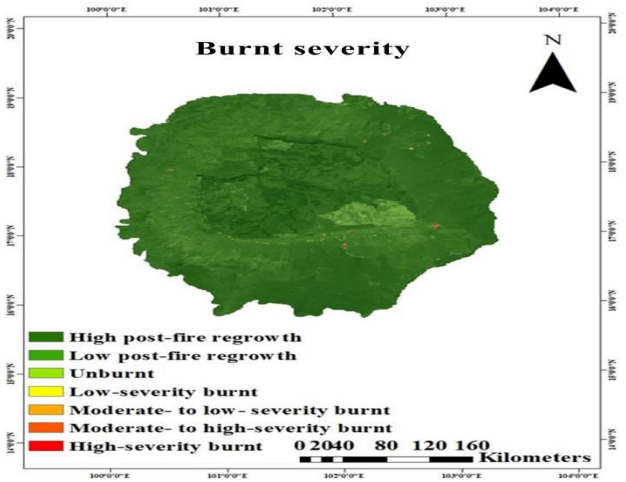

Figure-5. Distribution of severity of the burning.

The Outcome of the Examination on the Accuracy

In this study, the method was used by examining the accuracy of the outcome of the analysis by using overall accuracy and Kappa statistics. The accuracy of the forest areas being burnt by fire was examined by the method of visual interpretation from the data obtained from Landsat 8 OLI Satellite that pass the FCC procedure from SWIR - NIR - Red wave ranges (RGB: 754), being able to show the burnt area clearly, with the intensity of the color related to the severity of the burning. The

examples for the comparison of data obtained from the analysis and level of severity are shown in Figure-6.

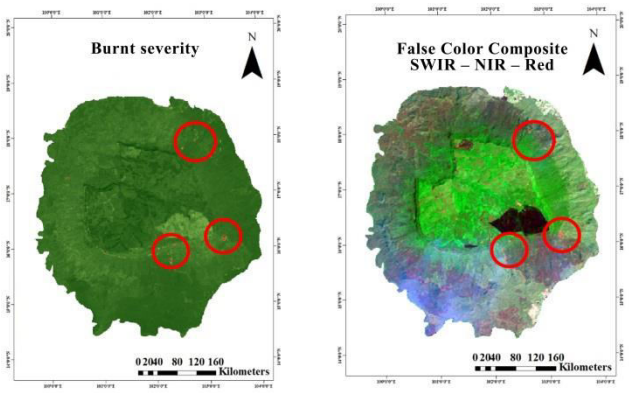

Figure-6. Comparison of data obtained from the analysis.

In other areas where the forest areas are burnt, the orange color is shown; and for the plants, the green color is shown; for the open area and agricultural area, the color is shown as white, pink, and light purple. The location was specified by creating 90 random points, dividing it into forest areas for 30 points, forest areas burnt by forest fire for 30 points, and other areas that are not forest for 30 points. The result of the study is shown in Table-3; overall accuracy is 94 % and Kappa statistics of the consistency is 0.87. When considering only the class of the burning area, it was found that the producer's accuracy is 89.66%, with an omission error of 10.34%, with the user's accuracy of 86.67% with a commission error of 13.33%.

Table-3. The result of Kappa statistics.

	Forest	Non-forest	Forest fire burnt	Sum	User's accuracy
Forest	29	0	1	30	96.67%
Non-forest	1	27	2	30	90.06%
Forest fire burnt	1	3	26	30	86.67%
Sum	31	30	29	90	
Producer's accuracy	93.55%	90.00%	89.66%		

CONCLUSIONS

Forest fire is the key problem that affects the ecological system and health of the people in the area. The forest fire in Thailand is caused by human activities which would be found during the dry season ranging from November to April. Mostly, forest fire happens in deciduous forest, dipterocarp forest, mixed forest, and wood lot. The attempt to identify the location, content, form, and distribution of burnt areas at the end of the fire season is very important to be the guideline for forest area conservation, the specification of policies concerned, and the management of forest fire in the area. The data obtained from Landsat 8 OLI Satellite can be used to analyze NBR and ΔNBR. In this study, it is possible to use it to assess the severity of the burning very well and is consistent with the situation happening in the area. Also, it is consistent with the examination of the accuracy of the forest areas being burnt by the method of visual interpretation.

As part of the result of the study into the severity of the burning, it was found that the level of severity of the burning is at a high level. The distribution map of the burning areas and the severity of the burning can be applied to the management of forest fires in the forest areas. Besides, this study also points out the analysis of NBR by using data from Landsat 8 OLI Satellite which makes it possible to identify the location and scope of the burning very well.

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