Identification on the burned forest area of Qipan Mountain using GF1-WFVsatellite image

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Abstract: In this study, GF1-WFV image was used with a spatial resolution of 16 m, which is higher than that of the commonly used MODIS, TM and other medium-high resolution satellites. Combined with the information extraction of pre-disaster forest and the ratio of NDVI in the two-temporal image before and after fire occurrence, the burned area, and its range after the “4.17” fire in Qipan Mountain in 2019 was analyzed. The results showed among the vegetable indices NDVI and EVI were better than GEMI and BAI in the extraction of burned forest area, while the radio of NDVI in two two-temporal was better than that of EVI. By using NDVI to extract forestland information before the fire occurrence and combining with NDVI ratio, it was most suitable to identify the burned area after a large range of forest fire in this area, with an overall accuracy of 92.2%.

1. Introduction

The information of the burned area is an important parameter and basic data for fire research [1]. Medium and low-resolution satellites such as MODIS, TM and other medium-high resolution satellites have high temporal resolution but are not suitable for monitoring small burned patches. TM and other high-resolution satellites have a long revisit period, which cannot satisfy the requirement of burned area extraction [2]. The GF-1 satellite is equipped with two PMS and four WFV cameras, which is the first satellite of China High-resolution Earth Observation System. The WFV image has the advantages of high spatial resolution (16 m), short revisit time (2 days), and 4 multi-spectral channels in the range of 0.45–0.90µm. It is more suitable for the identification of burned forest area information.

The identification of burned forest area is mainly to estimate the burned area by judging the spectral changes of vegetation before and after fire occurrence [3]. After fire, forest vegetation was destroyed; the damaged vegetation varies in different wavelengths reflectivity of satellite images, and is different from normal vegetation and other land. How to use high-resolution satellites to identify burned forest area and its boundaries more accurately is an important basis for measuring the fire area.

The vegetation index is a common method to identify the burned forest area by using remote sensing satellite. Scholars at home and abroad have used different satellite resources to evaluate burned forest area, and the main methods include vegetation index method, NDVI (normalized difference vegetation index) difference method before and after fire occurrence, NDBR (normalized difference burn ratio) difference method, HANDS (Hotspot and NDVI differencing synergy) method [3-5], etc. The main vegetation index methods included NDVI, NBR (normalized burn ration, NDII (normalized difference
of infrared index, NDWI (Normalized difference water body index), EVI (enhanced vegetation index), GEMI (global environment monitoring index), BAI (burned area index)[6], etc. Different vegetation indices have different applicability in different regions, and how to use vegetation index method to separate burned areas from other objects more effectively needed further research.

Based on GF1-WFV images before and after fire occurrence in Qipan Mountain, Shenyang, Liaoning Province, China, this paper compared the application differences of different vegetation index methods and selected a suitable method for the identification of burned forest area.

2. Materials and methods

2.1. Study areas
The Qipan Mountain is located in the semi-humid continental monsoon climate zone of the North Temperate Zone. It belongs to the remnant of Changbai Mountains, with an altitude of 100-441.3 m. The plant resources are rich in, mainly artificial forests, natural secondary forests and shrubs [7]. On April 17, 2019, a forest fire broke out in the Qipan Mountain of Shenyang, Liaoning province, China. The fire was completely extinguished until April 20.

2.2. Data resources
Satellite images before and after fire occurrence were selected to identify the burned forest area. GF1-WFV data used in this paper was from Land Observation Satellite Data Service Platform of China Center for Resources Satellite Data and Application (http://218.247.138.119:7777/DSSPlatform/index.html). The data was on April 16, 2019 (the day before the fire) and April 21, 2019 (after the fire was completely extinguished).

2.3. Data processing
The GF1-WFV images are all 1A level data products and should be preprocessed by radiometric calibration, atmospheric correction, geometric correction, etc. The data processing was completed in ENVI5.3 SP1 software.

2.4. Vegetable index methods
In this paper, NDVI, EVI, GEMI and BAI were used to identify the information of burned forest area. The formulas are as follows [6]:

\[
\begin{align*}
\text{NDVI} & = \frac{\rho_{\text{NIR}} - \rho_R}{\rho_{\text{NIR}} + \rho_R} \\
\text{EVI} & = 2.5 \frac{\rho_{\text{NIR}} - \rho_R + 6\rho_B + 7.5\rho_R}{\rho_{\text{NIR}} + 6\rho_R + 7.5\rho_R + 1} \\
\text{GEMI} & = \eta (1 - 0.25\eta) - \frac{\rho_R - 0.125}{1 - \rho_R} \\
\text{BAI} & = \frac{1}{2(\rho_{\text{NIR}}^2 - \rho_R^2) + 1.5\rho_{\text{NIR}} + 0.5\rho_R} \\
\end{align*}
\]

Where, \(\rho_R\), \(\rho_B\), \(\rho_{\text{NIR}}\) are red light, blue light and near-infrared waveband reflectivity.

2.5. Separability evaluation
The formula of separability using the M-statistic is as follow [8]:

\[
M = \frac{\mu_b - \mu_{\mu b}}{\sigma_b + \sigma_{\mu b}}
\]
Where, \( \mu_b, \sigma_b \) are the sample mean and standard deviation of the burned area pixels respectively; \( \mu_{\mu b}, \sigma_{\mu b} \) are the sample mean and standard deviation of other type area pixels respectively. When \( M \geq 1 \), it means a better separability; when \( M < 1 \), it means a poorer separability.

3. Results

3.1. Comparison of the images before and after fire occurrence

The preprocessed GF1-WFV images before and after fire occurrence were displayed by the pseudocolor composition (RGB: 3-4-2). Comparing the changes of the images, it was found that the color of the images before the fire (Figure 1) and after the fire (Figure 2) changed significantly, and the green information in the burned forest area disappeared.

![Figure 1. The pseudocolor composition image (RGB: 3-4-2) (before the fire)](image1)

![Figure 2. The pseudocolor composition image (RGB: 3-4-2) (after the fire)](image2)

The satellite image samples after the fire occurrence were extracted, including burned area, forest, water body, bare land, and construction land. The mean of five types of samples was calculated. Compared to the unburned forest sample, the reflectance in the near-infrared band of the burned forest was significantly reduced (Figure 3), which was obviously different from other sample features. The near-infrared band was a sensitive band for the identification of burned forest area.

![Figure 3. The wavelength reflectances in burned forest and other objects](image3)

3.2. Vegetation indices for identification forest fire area
The separability of burned forest area and other objects samples were higher by using NDVI and EVI, while these were poorer by using GEMI and BAI (Table 1). Therefore, NDVI and EVI were selected to identify the vegetation index of the burned area.

### Table 1. The separability of burned forest area and other objects samples

| Separability | NDVI | EVI | GEMI | BAI |
|--------------|------|-----|------|-----|
| Forest       | 3.65 | 3.37| 0.36 | 0   |
| Water body   | 2.77 | 2.69| 0.59 | 0   |
| Bare land    | 0.06 | 0.29| 0.68 | 0   |
| Construction | 0.63 | 0.51| 0.67 | 0   |

But it was poorer to separate burned forest area from bare and construction with NDVI and EVI, so the ratio of two-temporal (before and after the fire) in NDVI and EVI were calculated. The NDVI ratio has higher separability in separating the burned forest area samples from the bare and construction land samples but has lower separability in separating the burned forest area and water body (Table. 1). The EVI ratio has higher separability in separating the burned forest area and unburned forest, but lower in separating burned forest area and other objects (Table. 1). Therefore, NDVI before fire occurrence and NDVI ratios in two-temporal were combined to identify the burned forest area.

### Table 2. The separability of burned forest area and other objects samples

| Separability | NDVI ratio | EVI ratio |
|--------------|------------|-----------|
| Forest       | 3.06       | 1.36      |
| Water body   | 0.32       | 0.23      |
| Bare land    | 2.10       | 0.48      |
| Construction | 1.68       | 0.71      |

### 3.3. Identification on burned forest area with two-temporal NDVI

The images before fire occurrence were divided into three categories by using NDVI: water body, forest and other objects (Figure 4). The forest area was extracted as a mask, and the mask was applied in the ratio of two-temporal NDVI (Figure 5). The information of the burned area was extracted by the density slice method (Figure 6).

![Figure 4](Image)  The forest extraction before fire (forest in green, water body in blue and others in white)  

![Figure 5](Image)  The two-temporal (before and after the fire) ratio of NDVI
Figure 6. The burned forest area (red)

3.4. Precision Verification
The area of the burned area extracted by NDVI ratio method was 12.2 km², and the area extracted by visual interpretation method was 12.6 km². The overall accuracy of NDVI ratio was 92.2%, and the extraction effect was good.

4. Discussion
In previous studies, vegetation indices have been used to study the burned forest area. Gao et al. [9] used ETM image to identify burned forest area in Fujian Province and found that the accuracy of NDVI difference method was the highest. Tan et al. [10] combined GEMI-B and time series synthesis method to extract the grassland burned area in China and Mongolia in May 2003 by using MODIS satellite images, and resulted GEMI-B was more suitable than BAI, NDI, NDVI, and other indices. Fu et al. [11] combined NDBR and multi-band gradient edge analysis method to extract the information burned forest area in Great Xingan Mountain, Heilongjiang Province in October 2014 with MODIS images and believed that NDBR could better distinguish the burned intensity than NDVI. Bao et al. [3] used the HJ-1B-CCD image in April 2012 and SVM classification method to extract the burned forest area of Mongolian, with a total accuracy of 82.71%. Zu et al. [12] combined with NDVI, BAI, SVI, NDWI, and GEMI to construct a decision tree model, and extracted the burned forest area in Yajiang County, Sichuan Province in January 2014 by using GF1-WFV images. Wu et al. [13] used GF-1 satellite and near-infrared band B4, NDVI and GEMI to identify burned forest area in Dandong, Liaoning province, China, in April 2017, and found that B4 attenuation method was better than NDVI and GEMI in small patch burned area identification.

Different regions, seasons and burned ranges all affect the accuracy of burned area extraction. Considered vegetation changes before and after fire occurrence and heat characteristics at the fire time could more effectively identify the information of burned area [1]. In this paper, it was found that near-infrared band of GF1-WFV image was the most sensitive to the changes of green vegetation before and after the fire occurrence, so the vegetation index containing near-infrared band was used for burned forest area recognition. GEMI and BAI were not suitable for the study area; NDVI and EVI have higher separability in separating burned forest area from other objects; NDVI was better than EVI. However, the single NDVI might confuse the burned forest area and other objects. NDVI ratio method combining the information extraction of forest before and after fire occurrence, the accuracy of burned area extraction was up to 92.2%.

5. Conclusion
For Qinpan Mountain in spring, the burned forest area might be easily confused with bare land or forest
in low NDVI. To avoid this, NDVI was used to extract forest area and then NDVI ratio of two-temporal image before and after fire occurrence was used to extract the burned area. Results showed it was suitable for a larger burned range extraction in the study area.

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