Study on the forest vegetation restoration monitoring using HJ-1A hyperspectral data

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Abstract. In this paper, Xunke County was studied using HJ-1A hyperspectral data for monitoring vegetation restoration after forest fires. The pre-processing procedure including data format conversion, image mosaicking and atmospheric correction. Support vector machine classification was used to perform surface feature identification based on the extracted spectral end-members. On that basis, the image area was divided into seven categories and statistical analysis of classification types was performed. The results showed that HJ-1A hyperspectral data had great potential in fine classification of surface features and the accuracy of classification was 91.8%. The mild and severe fire-affected area extraction provided useful reference for disaster recovery monitoring. Furthermore, the distinction between coniferous forest and broadleaved forest can offer useful information for forest fire prevention and early warning to some extent.

1. Introduction
Fire hazard is one of the most serious damage to forest, so forest fire monitoring is very important. The forest fire monitoring method of observation tower or aircraft survey is limited in observation range and frequency, however, the technology of satellite remote sensing has the advantage of large range, efficient and low-cost observation, and can play an important role in forest fire monitoring. So far China has achieved considerable development in the remote sensing monitoring forest fire, such as the fire remote sensing monitoring service system has been established which include forest fire-points identification and monitoring, burned area calculation, restoration assessment, and so on.

On September 6th, 2008, two optical environmental satellites were successfully launched in the Taiyuan Satellite Launch Center, one of the satellites called HJ-1A equipped with an imaging spectrometer, which is the first spaceborne earth observation hyperspectral imaging spectrometer. Hyperspectral remote sensing has the characteristic of combining spatial dimension and spectral dimension. It can improve the accuracy of remote sensing image classification⁴, and can be applied to forest fire monitoring. In this paper, HJ-1A hyperspectral data were applied for monitoring vegetation restoration, where was destroyed by forest fire in Xunke County, Heilongjiang province, 2009, and the paper studied primarily on technical route and method.
2. Survey of study area and RS data

2.1. Survey of study area
Heilongjiang province is one of major forest regions in China and is the forest fire prone area. On April 27th, 2009, catastrophic forest fires occurred in Yinan River forest and the fires extended to neighboring counties and cities.

In this paper, the seriously fire-affected area in Xunke county was studied to monitor vegetation restoration. This region is located in mid-high-latitude and the climate types are cold-temperate continental monsoon climate. The main forestry resources in this area are cold-temperate coniferous forest and temperate deciduous broad-leaved forest.

2.2. Survey of HJ-1A hyperspectral data
The main task of HI-1 satellite is to monitor dynamically disasters in large range, all-weather and all-time, then provide scientific basis information for emergency rescue, disaster relief, recovery and reconstruction[2,3]. Through subdivision of spectral bands by hyperspectral imager, in the spectral dimension, each image pixel can form a complete and continuous spectral curve, thus it can react more detailed object radiation characteristics.

Table 1. Index of HJ-1A hyperspectral data.

| Index          | Parameters          |
|---------------|---------------------|
| Width         | ≥ 50km              |
| Spectral range| 0.45〜0.95 μm       |
| Spectral resolution | 5 nm             |
| Space resolution | 100 m           |
| IFOV          | ± 30º               |
| Band number   | 115                 |
| S/N           | 50〜100              |
| Accuracy of calibration | Relative 5%, Absolute 10% |
| Quantization levels | 12 bit           |

The parameters of HJ-1A hyperspectral imager is listed in the above table. Unlike the other hyperspectral data such as EOS, MODIS, EO-1 Hyperion, HJ-1A has narrower spectral range, but has higher spectral resolution of surface features, which is important especially to vegetation identification and information extraction.

This paper choose two HJ-1A hyperspectral images on May 24th, 2009, the geographical range of longitude is 128°30′-129°20′, and latitude is 48°25′-49°19′.

3. Restoration monitoring after fire disaster

3.1. Technology and methods
The monitoring restoration with HJ-1A hyperspectral data includes three steps as follows, as shown in Figure 1.
- Data preprocessing. This preprocessing include format conversion, image mosaicking, as well as atmospheric correction with 6S radiation transfer model.
- Endmember selection. Endmember selection is to find the training area by hyperspectral data endmember extraction and image characteristics.
- Classification mapping and results output.
3.2. Data preprocessing and analysis

3.2.1. HDF5 format conversion.
HDF5 is the storage format of HJ-1A satellite hyperspectral data, and it is a self-descriptive, scalable, self-organizing data storage format, using a binary tree to establish the file index of contents, which make the data access quickly and easily\cite{4}. HDF5 format is not compatible with common remote sensing software platform such as ENVI, ERDAS, therefore, it's necessary to convert the image format compatible with remote sensing software platform before the data is processed. In this paper, IDL language is used to development module to read the HDF5 format, and then convert it to the format which can be read by the ENVI software.

3.2.2. Atmospheric correction.
Hyperspectral data of HJ-1A satellite is the level 2 products, which has been processed by system radiometric calibration. DN value of image is the record of entrance radiation, so it is need to convert DN value to reflectance value by atmospheric correcting, and it make smoothly to do the following information extraction in the practical application.

In this paper, the 6S radiation transfer model is used for atmospheric correction of HJ-1A hyperspectral data, the 6S model developed on the basis of the 5S model in 1996 by the atmospheric optics laboratory in France. 6S model absorb the latest scattering calculation, and use the latest approximation and the successive orders of scattering algorithm to calculate the scattering and absorption, which take into account the non-Lambertian of surface. It calculate the transmittance with the addition of CH\textsubscript{4}, N\textsubscript{2}O and CO gas. and it improve the calculation accuracy of the Rayleigh scattering and aerosol scattering. The effective wavelength range is 250~4000nm\cite{5}. The input parameters in 6S model are geometrical conditions, atmospheric model, spectral condition, target & sensor altitude, ground reflectance and so on.

3.3. Endmember and training samples selection.

3.3.1. Minimum noise fraction rotation (MNF).
MNF transform can determine the dimension of the image data, separate the noise in the data and reduce the amount of data. After MNF transformation, eigenvalue of each component is decreasing. Component of larger eigenvalue contains the main information, and component of small eigenvalue
contains almost the noise. The purpose of MNF transformation is to make useful information into limited minority component so as to improve the efficiency of endmember extraction. After the MNF transformation of reflectance data, images of 2nd, 4th, 6th and 8th component are showed in Figure 2. It can be seen from the image that the 2nd component image has amount of information almost without noise, followed by 4th component, and the 6th and 8th component gradually reduce the information and increase the noise.

![Image of component images](image_url)

**Figure 2.** Feature components after MNF transformation.

3.3.2. *Pixel purity index (PPI).*

PPI tool repeatedly projects vector of pixel spectrum onto the unit vector of random direction, the statistic number of pixel in each unit vector endpoint or close to the endpoint is recorded as DN value of the image purity pixel. The greater DN value means the higher purity pixel. In this paper, the top 15 MNF components are calculated in PPI tool, and a relatively pure pixel data set of spectra is established as to extract endmember from image.

3.3.3. *Analysis in n-Dimensional visualizer.*

The pure pixel data sets are extracted and inputted to the n-dimensional visualization analysis tool by setting the threshold. By rotating the plots of n-dimensional scattered points and combining with the points corresponding image pixels, endmembers are interactively selected which are points located in the periphery or end of the shaft in the n-dimensional space. In this paper, seven categories are identified in study area, as shown in Figure 3.

![Image of n-Dimensional visualizer](image_url)

**Figure 3.** End-member spectra extraction.

- Coniferous forest spectral feature is higher reflectivity relative to broad-leaved forest, and is deeper absorption depth of "Red Valley".
- Broad-leaved forest spectral feature is lower reflectance relative to coniferous forest.
- Mild affected region spectral feature is lower reflectance relative to normal vegetation, it indicate that there is still small amount vegetation, and where is relatively easy to restore.
- Severe affected region there is no vegetation spectral features, it indicates that the vegetation has been destroyed seriously and is relatively difficult to restore.
- Bare region there is no vegetation distribution and there is the high reflectivity.
Valley is located between mountain and woodland with no vegetation distribution, the reflectivity curve is relatively flat.

- Water is the lowest reflectivity.

3.4. Image classification.
In this paper, support vector machines (SVM) is used to image classification. SVM, proposed by Vapnik, is a machine learning method according to the statistical theory[6]. Since support vector machine has solved many practical problems such as the small sample, nonlinear, high dimension and local minima points and has high accuracy classification results, it has become the preferred tool to classification[7]. The kernel function of SVM is used to implement the mapping from the low-dimensional space to a high dimensional space, and acquire classification function of the high-dimensional space. Different kernel functions will lead to different SVM algorithm. In this paper, the radial basis kernel function (RBF) is used to build the SVM algorithm which has the advantage of handling a variety of non-linear relationship with few parameters.

SVM classification is used for supervised classification to reflectance data after atmospheric correction, and the results of classification shown in Figure 4b.

![Figure 4](image_url)

Figure 4. Classification result of surface features using HSI data.

3.5. Analysis of precision.
In high-resolution CCD image, the region of each class is selected as the evaluation criteria of classification results corresponding to hyperspectral image for the evaluation of classification accuracy. Shown in Table 2, the confusion matrix and kappa coefficient are calculated. The results show that small amount of misclassification exist between the conifer and broad-leaved forest, because of their similar feature spectral curves, and the only difference of reflectivity level. Similar phenomenon also appear between the mild affected fire region and broad-leaved forest region. Image features and spectral features of severe affected region distinguish with the other categories evidently, not appearing the phenomenon of misclassification. Overall, the accuracy of classification is high.
Table 2. Confusion matrix of classification.

| Classes       | Coniferous | Broad-leaved | Water | Bare | Valley | Severe | Mild | Total |
|---------------|------------|--------------|-------|------|--------|--------|------|-------|
| Coniferous    | 112        | 16           | 0     | 0    | 0      | 0      | 0    | 128   |
| Broad-leaved  | 7          | 115          | 0     | 0    | 0      | 0      | 24   | 146   |
| Water         | 0          | 0            | 125   | 0    | 0      | 0      | 125  | 250   |
| Bare          | 0          | 0            | 0     | 114  | 18     | 0      | 0    | 132   |
| Valley        | 0          | 0            | 2     | 96   | 0      | 0      | 98   | 204   |
| Severe        | 0          | 0            | 3     | 0    | 0      | 139    | 0    | 142   |
| Mild          | 0          | 0            | 0     | 0    | 0      | 0      | 85   | 85    |
| Total         | 119        | 131          | 128   | 116  | 114    | 139    | 109  | 856   |

The overall classification accuracy: 91.8%  
Kappa Coefficient: 0.9044

4. Conclusions
In this paper, hyperspectral data of HJ-1A was used to compartmentalize severe affected forest fire region and mild affected forest fire region. The above provides a useful reference for disaster recovery and monitoring. In addition, deciduous broad-leaved forest is susceptible to fire in autumn and winter due to a lot of dry leaves on the ground. The use of hyperspectral data classification between conifer and broadleaf forest provides basis for the forest fire warning. The above study has shown that HJ-1A hyperspectral data can reflect the difference of objects feature spectra after forest fire. The classification results can meet the needs of majority of vegetation information extraction. However, there are still some problems in the processing of HJ-1A hyperspectral data, for example, there is a lot of noise in some bands which resulted in information loss, and the curve of relative reflectivity is not smooth enough causing abnormal reflection peak. We will focus on these problems. Overall, HJ-1A hyperspectral data has great application potential in forest fire monitoring and will provide important decision support for disaster reduction.

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