Assessment of Vegetation Recovery after Forest Fire

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Abstract: The land cover of burned area has changed dramatically since Daxinganling forest fire in Northeastern China during May 6 – June 4, 1987. This research focused on determining the burn severity and assessment of forest recovery. Burned severity was classified into three levels from June 1987 Landsat TM data acquired just after the fire. A regression model was established between the forest canopy closure from 1999 forest stand map and the NDVI values from June 2000 Landsat ETM+ data. The map of canopy closure was got according to the regression model. And vegetation cover was classified into four types according to forest closure density. The change matrix was built using the classified map of burn severity and vegetation recovery. Then the change conversions of every forest type were analyzed. Results from this research indicate: forest recovery status is well in most of burned scars; and vegetation change detection can be accomplished using postclassification comparison method.

Keywords: Forest Fire, Vegetation Recovery, Burn Severity, Forest Canopy Closure, Postclassification Comparison.

1. Introduction

Forest fires contribute significantly to climate changes and soil degradation. The destruction of vegetation by forest fire can affect profoundly the structure and function of forest ecosystems. Operational monitoring and forest recovery assessment of burned areas is very important in dealing with emergency situation and quantitative estimation of the affected area. The development of high spatial resolution remote sensing instruments has provided an opportunity to evaluate patterns of vegetation recovery over burn scar. Landsat Thematic Mapper imagery has been widely used to estimate forest characteristics [1]. After the fire, significant reduction of the vegetation is expected and values corresponding to complete lack of chlorophyll elements are an indication of the burned area. Vegetation indices can be used to identify vegetation changes. The intent of the research was to assess the vegetation recovery after a forest fire, and to link the observed changes to differences in the severity of the burn.

2. Study Site and Data Description

1) Study Site

The Forest fire during May 6 – June 4, 1987 in Daxinganling forest region of Northeastern China burned 1.14 million hectares of forest and nearly 25 million cubic meters of timber [2]. Changqing Forest Farm was selected as our study area. It is located in the north of Daxinganling and has suffered the 1987 forest fire. The main forest species in this region are Dahurian Larch (*Larix gmelii*), Mongolian pine (*Pinus Sylvestris var mongolia*), and some broadleaf species, such as Asian White Birch (*Betula platyphylla*), David Poplar (*Populus davidiana*), Willows, Mongolian Oak (*Quercus mongolica*) and Dahurian Birch (*Betula dahurica*). About 70% of the forests were larch stands before the fire.

2) Data Description

The remote sensing data used in this study include Landsat-5 TM image of 15 June 1987, Landsat-7 ETM+ image of 10 June 2000, and 1999 forest stand map. The image of 15 June 1987 was collected just after fire and showed the fire severity clearly. The image of 10 June 2000 acquired 13 yeas after fire indicated status of vegetation recovery. The forest stand map according to the field survey data by Daxinganling Academy of Forest Inventory, Planning and Design was digitalized (Fig.1).
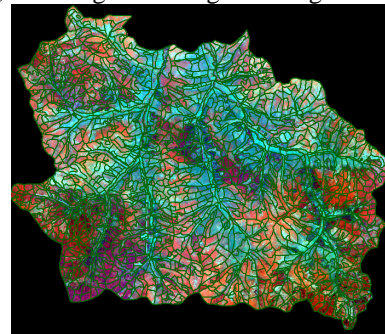

Fig.1: Digitalized Forest Stand Map of Changqing Forest Farm in dark green (The base map is Landsat 7 ETM+ image of June 2000, RGB is Band 4, 5, 3)

In forest stand map, the smallest unit is forest stand subcompartment which is also the smallest operational unit in China forest management planning. The soil, relief, tree status are in the same level in a subcompartment. The attributes of each stand compartment are collected by field measurements. In the digital forest stand map, each polygon is corresponding to a forest stand subcompartment. According to the attribute of stand subcompartment, we assumed the spectral attributes of each forest stand subcompartment are same. So we can select some polygons from the digital forest map and regress the attributes (e.g. dbh, age, height, crown density, volume density etc.) of these polygons with remote sensing data values.

3. Data Analysis and Results

The electromagnetic radiation signals collected by the satellites in the solar spectrum are modified by scattering and absorption by gases and aerosols while traveling through the atmosphere from the Earth's surface to the

sensor. So the atmospheric correction is necessary when using the two period data to do the change detection [3]. The dark object subtraction (DOS) approach was used in this study. Then the DN value was conversed to radiance with the gains and biases provided in the head file. All Landsat TM data were registered to a common Universal Transverse Mercator Projection by control points.

The methodology adopted for this study involved classifying two dates of TM data into several classes and then analyzing the change using a matrix operation [4].

1) Fire Severity Classes

An unsupervised approach was chosen for Landsat-5 TM image of 15 June 1987. The fire severity was classified to three degrees which were lightly burned, moderately burned and heavily burned (Fig.2).
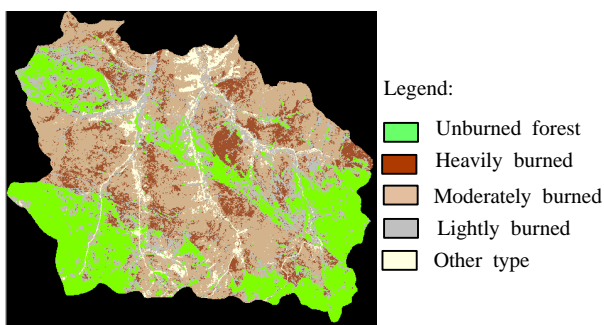

Fig.2. Map of Burn Severity Classes

2) Post-fire Vegetation Recovery

Forest canopy closure is one of the most useful parameters to consider in the planning and implementation of rehabilitation program. As an essential parameter for characterization of forest conditions, forest canopy closure was used to indicate the quality of forest recovery in this research.

In the field of remote sensing application, scientists have developed vegetation indices (VI) for qualitatively and quantitatively evaluating vegetative covers using spectral measurements. Over forty vegetation indices have been developed in order to enhance vegetation response and minimize the effects of the factors described above. Among the vegetation indices, the Normalized Difference Vegetation Index (NDVI) is the least affected by topographic factors and is sensitive to the presence of green vegetation [5].

There is a quantitative relation between NDVI values and forest canopy closure [6]. In the study area, the NDVI image was acquired from Landsat-7 ETM+ data of 10 June 2000. In digital forest stand map, forests were classified into three types which were conifer forest, broadleaf forest and mixed forest. In each type of forest, more than 50 stand polygons were selected to extract the stand canopy closure attributes. The AOIs (area of interest) were generated according to the selected polygons and calculated the average pixels' value in each aoi. So we have the corresponding values between the image and the in-situ measurement. Then we merged all the

three forest type data together to do the analysis between forest canopy closure and NDVI. According to the plot graph, the linear regression model was selected in this study. The correlation coefficient is 0.600405 and the regression equation is:

$$ClosureDensity = 0.181029 + 0.566979NDVI$$

Fig.3 shows the line fit relation. From above regression equation and figure (Fig.3), there is certain correlation between forest canopy closure and NDVI. If the ETM+ data and forest stand map were acquired at the same year, the results would be better.
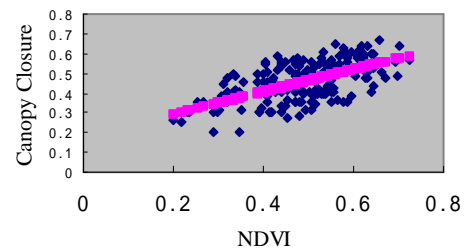

Fig.3. Canopy Closure-NDVI Line Fit Plot

According to the equation, the canopy closure was inversed. Then the forest types were classified based on the values of forest canopy closure (Fig.4). The forest classes are: forest of high canopy closure (FCC>0.5), forest of medium canopy closure (FCC: 0.4-0.5), forest of low canopy closure (FCC: 0.3-0.4), and other type (FCC <0.3).
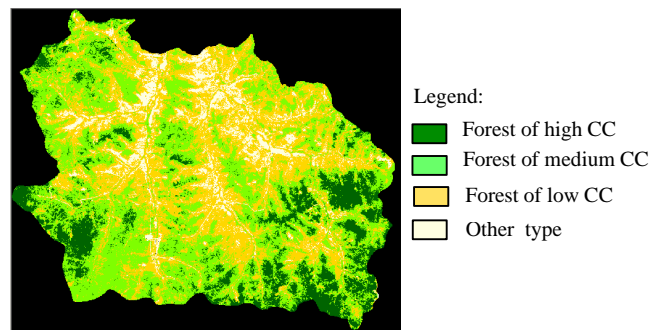

Fig.4. Map of Forest Canopy Closure Classes

3) Vegetation Changes Detection and Assessment

Comparison of the datasets after classification can remove much of the effect of the sensors properties. Using a postclassification comparison allows each date of data to be classified into desired land-cover classes based on the inherent characteristics of the data. Additionally, this removes the need to normalize images to each other, and holds any inherent data defects within the single dataset.

The method of postclassification comparison was used in this part. Base on maps of burn severity classes and forest canopy closure classes, 2000-6-10 ETM+ classification image subtracts 1987-6-15 TM classification image using the map algebra method. After statistics and comparison, we got a transformation table of forest type

(Tab.1) and transformation map of forest type (Fig.5).

Tab.1. Transformation Table of Forest Type

2000 \ 1987	Forest	Heavily burned	Moderately burned	Lightly burned	Other type
Higher canopy closure (CC)	5076	675	1989	1494	54
Medium CC	9279	2979	9819	4833	531
Lower CC	2880	3825	11727	4086	1728
Other type	279	990	2727	1017	1116

Annotation: Figures in the table indicate the forest type transformation area from 1987 to 2000. The unit is hectare.
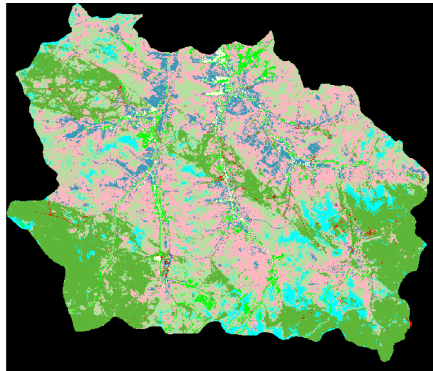
Legend:

- Forest of higher canopy closure
- Other type → Forest
- Burned area → Forest of medium canopy closure
- Burned area → Forest of high canopy closure
- Burned area → Forest of low canopy closure
- No recovery (Burned area → Other type)
- Degraded forest (Forest → Other type)
- Other type

Fig.5. Transformation Map of Forest Type

Twenty pairwise combinations (Table1) were developed from the five classes of 1987 and four classes of 2000 and then recoded into eight specific change classes (Fig.6). Recoding served both to reduce the original number of classes created by the matrix operation and to establish the comparison at the same level (burned area). The results show that: most of burned area in Changqing Forest Farm has recoveried to forest status. Only little of burned area hasn't recovery to forest. The unburned forest still has kept the good growth ability. Small part of unburned forest has degraded.

In Tab.1, the total number of hectares for each change class is listed for each burn class. Then we analyzed the percent changed of forest recovery based on each burn class (Fig.6).

Change class statistics for each degree of burn severity were generated, giving the total amount of change experienced by a cover type for each class of burn. The proportion of changing to high canopy closure forest was lowest and the percent of changing to low canopy closure is highest in heavily burned areas. The percent of changing to high canopy closure forest in lightly burned area is larger than in heavily burned areas. It shows that forest regrowth ability of heavily burned areas is lower than that of lightly burned area.
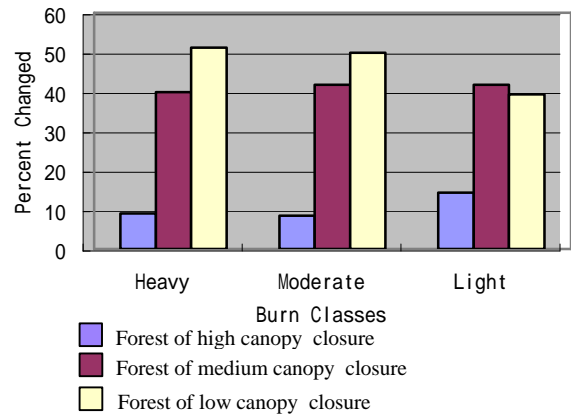

- Forest of high canopy closure
- Forest of medium canopy closure
- Forest of low canopy closure

Fig.6. Percent Change for Each Vegetation Class in Each Category of Burn Severity

4. Conclusions

Patterns of post-fire vegetation recovery and change were evident in the classified Landsat data. In this study, two dates of Landsat data were used to assess vegetation recovery after over ten years fire based on postclassification comparison method. The results demonstrate the possibility of monitoring forest recovery quantitatively and making right judgments about specific relationship of burn severity to vegetation recovery using remote sensing data and forest investigation data. The associated results also agree well with vegetation regrowth trends observed in the field observations of fire damaged areas.

Acknowledgement

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