Vegetation change detection based on TM and SPOT images spectrum fusion in the typical area of Xishuangbanna area

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Abstract. There are many tropical forest resources in Xishuangbanna area; it is a very important status in China. But because a large number of rubber plantations are expanding as far as possible and the areas of urban construction land are increasing, the areas of tropical forest are decreasing rapidly, which lead to serious fragmentation. In the paper, we choose the typical area of Xishuangbanna area as the research area to study the vegetation change trajectory using ETM and SPOT images acquired on different time. On the base of data pretreatment, two aspects researches were carried out. On the one hand, spectral information and NDVI information of each type of vegetation were analyzed to classify the ETM and SPOT images using the method of decision tree respectively. By classification post-processing, we could get the ways of the vegetation type conversion. On the other hand, ETM and SPOT PAN Images were integrated by the PCA to acquire the information of vegetation change including vegetation gain or loss. Finally, comprehensive information on two aspects of the vegetation changes was analyzed to acquire the vegetation change trajectory from 2000 to 2007 in the Xishuangbanna area. The result showed vegetation conversions that changed from one type to another type were frequent. A larger proportion of other type vegetation was transformed to rubber plantations.

Introduction

Xishuangbanna is a significant region in China that has abundant tropical forest resources, vegetation are rich and seasonal obviously. But in recent years, the area of rubber plantation are increasing rapidly accompanied by mountain contracted to household and rubber income increase, annual increasing about $3.0 \times 10^4$hm$^2$. The area of rubber plantation has reached $24 \times 10^4$hm$^2$ in 2008[1], as opposed to a significant reduction of tropical seasonal rainforest in the region. The ratio of forest coverage has declined from 60% of the 1950’s to 27% of the early 1990’s [2]. The forest fragmentation is severe, degradation is apparent. Simultaneously, the demands of land use, construction timber and firewood consumption are rapidly increasing because of increasing population, which exacerbate the decrease of tropical rain forest area and destruction of habitats [3]. So, the further research of vegetation change is conducive to the vegetation protection and healthy development of rubber plants in Xishuangbanna.

With the development of remote sensing and GIS technology, multi-spatial, multi-spectral and multi-time resolution of the remote sensing data and spatial analysis of GIS make the vegetation research become a hot spot using 3S technology. Most of researches of vegetation changes using remote sensing are based on the same sensor. But it is difficult to obtain continuous time series images because of atmospheric effects in some regions. The methods of remote sensing image
fusion would be used to monitor vegetation changes by different remote sensor. For this field, scholars have conducted a number of related researches [4]. From this perspective, this paper explores the integration of TM and SPOT instrument data for vegetation change detection in Xishuangbanna.

Methods

Research would be launched as follow: first, the remote sensing images were preprocessed, including image to image registration and radiometric calibration. Secondly, based on prior knowledge (field samples), TM and SPOT images were classified by decision tree to obtain classification maps in different periods. Through post-classification comparison, how to transform one type of vegetation to another type of vegetation would be analyzed in space. Finally, multi-temporal fusion images would be acquired by the methods of different sensors image fusion to monitor vegetation changes, analyzing trajectory of vegetation changes.

Xishuangbannan is located in Yunnan province, southwest China, 99 ° 56' ~ 101 ° longitude 51', 21 ° 08' ~ 22 ° 36' latitude. The area is 19125 km2. Vegetation distribution represents a horizontal and vertical zonal characteristic. Seasonal rain forest is in 600m-1000m, tropical montane rain forest is almost in 850m-1000m, pinus khasys is above 1500m [5]. Forest coverage rate is 63.68%, main vegetation types are tropical rain forest, tropical monsoon forest, subtropical evergreen broad-leaved forest, warm coniferous forest, bamboo forest, secondary vegetation, shrub and grass et al. there are 8 forest types, 13 vegetation subtypes and 29 formations [6, 7].

In this paper, the study area is located in the central of Xishuangbanna, 100 ° 37' ~ 101 ° 14', 21 ° 40' ~ 22 ° 20'. As shown in Fig.1 (the red region), its elevation is from 486m to 2188m, the west region is mountainous with high elevation, which has typical vegetation features of Xishuangbanna. Like other regions of Xishuangbanna, the fast expansion of rubber plantation occupies a large number of other vegetation habitat spaces. Based on the technique of different sensors fusion, various kinds of vegetation changes trajectory were analyzed to understand vegetation changes and provided a reference for the vegetation protection.

Data sources and processing methods. Two sensor data were used: Landsat ETM and SPOT HRG and PAN. ETM was acquired on 14 March 2000; the SPOT image was acquired on March 2007. Two images were obtained in the same month, which had similar vegetation growth condition to compare vegetation changes.

Image registration and atmospheric calibration are two necessary aspects in the image preprocessing procedure. The accurate registration of multi-temporal images is important to produce credible results of change detection, otherwise, to lead to spurious results [8]. An image-to-image registration between ETM and SPOT images was performed. The SPOT PAN image was used as a reference image. The registration accuracy of SPOT HRG was 0.51 pixels; ETM was 0.62 pixels, which were less than 1 pixel to meet the requirements of monitoring vegetation changes.

For different sensors, pixel DN values stand for different significance. Therefore, radiometric calibration and atmospheric correction which convert DN to radiance or surface reflectance is a requirement for quantitative analyses of multi-temporal images. In this paper, Quick Atmospheric Correction (QUAC) was used for the atmospheric calibrations of ETM and HRG images by the software ENVI 4.7.

Image classification. Decision tree classification based on prior knowledge is used for image classification. In tropical and subtropical regions, it is possible to lead to false classification if spectral characteristics are only used for image classification due to diverse vegetation types,
complex structure. [9]. Therefore, vegetation distribution range is acquired more accurately by using spectral information of field sample points and NDVI calculated by the bands of ETM and SPOT [10]. In the region, 63 field samples covering 6 kinds of landscape types were collected: rubber plantation, primary vegetation (no or less human disturbance of vegetation), secondary vegetation (after the growth of human disturbance out vegetation), artificial planting (except rubber plantation outside), bare land, and water. Paper is focusing on monitoring 6 kinds of landscapes and conversion relationship of different landscapes in the space. NDVI and bands spectrum information of field samples were extracted from the ETM and SPOT HRG images. Different landscape types had the different spectral features of an ETM image, especially, in band 4 and 5.

It was difficult to distinguish landscape types depending on reflectance merely because their reflectances were close to each other. The classification should be completed by constructing rules combining NDVI and reflectance. The reflectance of different landscape types was different significant in short-wave infrared band. Therefore, paper used this band and NDVI to construct rules of decision tree classification. As Fig.2 shown, the threshold values were determined from the sample plots based on the comprehensive analysis of images. According to decision tree classification rules, the ETM and SPOT HRG classification maps were obtained by decision tree classification module in ENVI 4.7, as shown in Fig.3. Comparison of the two time classified images indicated that the areas of rubber plantation and bare soil and building were increasing, the primary and secondary forest were decreasing, the reducing areas were located in around rubber plantation, artificial vegetation (except rubber plantation) were also decreasing.

In order to use the classified images for vegetation change detection with post-classification, it is necessary to confirm that the classified images have high classification accuracies. A total of 100 samples were randomly produced on the classified images to accuracy test. The overall accuracies of ETM and SPOT classified images were 92.3% and 93% respectively. These accuracies were satisfactory for the detection of landscape type changes.

**Remote sensing data fusion.** Remote sensing image fusion is a processing procedure of multi-sensors images data and other information. Due to different remote sensing data fusion containing a time factor, it has change detection capabilities. In this paper, the method of principal component analysis (PCA) was used to fuse ETM and SPOT images. The ETM multi-spectral band images (1 to 5 bands and 7 bands) and SPOT PAN panchromatic image were fused to obtain fused image ETM$_{fuse}$ that contained six bands and both information of ETM multispectral and SPOT panchromatic images. The vegetation change trajectory could be analyzed by comparing band5 of ETM images and ETM$_{fuse}$. Because the short-wavelength infrared band contains the most information to monitor the vegetation change decision better [11]. Conduct image difference between the bands of fusion image and corresponding ETM bands: images subtraction and set the threshold for analyzing vegetation change trajectory. The thresholds were determined by the region that vegetation types remained unchanged. Within the thresholds region, vegetation didn’t change; less than the thresholds region, vegetation improved; greater than thresholds region, vegetation declined. For example, in a region, through vegetation types did not happen to change, the value was less than the threshold which indicated that the vegetation was declining.

**Results**

The results involved two aspects about monitoring vegetation changes: vegetation type conversion and vegetation change trajectory (such as vegetation recession and vegetation improvement), which were acquired by the methods of remote sensing images classification and fusion. Integrating the two aspects results, the complete vegetation change map would be acquired in the study area. The
map not only reflected the situation of vegetation type conversion (vegetation from one type to another type in a region), but also the vegetation change trajectory (vegetation improvement or recession in a no type change region), which is in favor of a more comprehensive and monitoring the vegetation change situation in detail in the region.

From the two stage images classification maps above, the maps of vegetation type conversion relationship could be obtained from 2000 to 2007. Vegetation changes were dramatic from 2000 to 2007. Specific conversion proportion as shown in Table 1

<table>
<thead>
<tr>
<th>2007</th>
<th>Rubber plantation</th>
<th>Primary vegetation</th>
<th>Secondary vegetation</th>
<th>Artificial vegetation (except rubber plantation)</th>
<th>Bare soil and building land</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber plantation</td>
<td>22.599</td>
<td>19.416</td>
<td>9.483</td>
<td>9.248</td>
<td>3.383</td>
<td>0.443</td>
</tr>
<tr>
<td>Primary vegetation</td>
<td>13.233</td>
<td>41.551</td>
<td>13.663</td>
<td>3.992</td>
<td>1.253</td>
<td>0.581</td>
</tr>
<tr>
<td>Secondary vegetation</td>
<td>13.833</td>
<td>15.215</td>
<td>20.8</td>
<td>7.745</td>
<td>4.615</td>
<td>0.4</td>
</tr>
<tr>
<td>Artificial vegetation</td>
<td>33.319</td>
<td>13.331</td>
<td>23.493</td>
<td>37.846</td>
<td>27.982</td>
<td>1.136</td>
</tr>
</tbody>
</table>

Vegetation change trajectory was obtained by application of remote sensing image fusion of different sensors at different phase. Fig.4 showed a comparison of images before and after images fusion, in the Fig.4a, the darker color regions stood for vegetation, the lighter color regions stood for bare soil and building land on ETM band 5 acquired 2000. The Fig.4b showed the fusion band 5 images using the PCA approach based on ETM acquired 2000 and SPOT PAN acquired 2007. Comparison of two images showed that some darker regions on ETM band 5 acquired 2000 became shallow on fusion image, which account for the vegetation recession in these regions (Fig.4 marks). These changes always occurred in the edge of darker region, indicating the vegetation type conversion occurred in the junction of two zones of vegetation. So, comparison images of before and after fusion reflect the vegetation changes information.

ETM band 5 was subtracted from the fusion image band5 to get Fig.4c. In the Fig.4c, the lighter color regions stood for vegetation recession or degradation regions, the darker color regions stood for vegetation improvement, the medium color regions indicated that vegetation was unchanged. According to a certain threshold (these thresholds were derived from the unchanged primary vegetation, bare soil and building areas et al), the Fig.4c were reclassified to make vegetation change information more clearly, as shown Fig.4d. The yellow area was the vegetation improvement, the green stood for unchanged vegetation, the blue stood for vegetation recession. Compared to the vegetation type distribution map, the areas of vegetation improvement were primary vegetation and rubber plantation; the regions of vegetation recession were bare soil and building land. In addition, in Fig.4c and Fig.4d, water changes didn’t accord with actual situation that the two images appear loss because water reflection value on the SPOT PAN and ETM images was quite different in the process of images fusion, the specific explanation in [8].

Compared to traditional change monitoring methods, more complete precise vegetation change trajectory could be obtained by the method of combining remote sensing image classification and fusion images. As shown Fig.5, it contained vegetation type conversion and vegetation change information. In white region, vegetation did not change any more, namely, vegetation type did not convert; vegetation did not decline or improve. In blue region, vegetation type also did not convert,
but vegetation became better (this vegetation change probably happened from young to mature or result from the improvement of vegetation condition by manual). In dark green region, vegetation type did not convert but vegetation became worse (this vegetation change probably came from the natural death of vegetation communities, self-thinning and small-scale fire or human intermittent felling). Other colors indicated vegetation changed. The integration approach of remote sensing image classification and fusion image decomposition was so precise to obtain vegetation change information. Such the comprehensive image analysis method was conducive to vegetation protection, especially when it was difficult to obtain sequential time images of the same sensor data and lots of field samples data.

Conclusions

The traditional approach based on remote sensing image monitoring vegetation use different time remote sensing images from the same sensor and a lot of field reference data. But for the Xishuangbanna region, it is difficult to acquire these remote sensing images, or even if such image can be obtained, the image resolution is always lower not to meet accuracy need. Therefore, using different sensors ETM and SPOT images, vegetation change situation was analyzed by the methods of decision classification and image fusion based on PCA. The information of vegetation type conversion could be obtained accurately by decision tree classification and post-classification comparison, the information of vegetation change (vegetation improvement or recession) could be obtained by image fusion based on PCA. Vegetation change situation could be analyzed accurately by integration of two approaches in the study area. The results indicated that vegetation change was obvious, the area of vegetation conversion was large, other type vegetation mostly was converted to rubber plantation and bare soil and building land.

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Reference

Fig. 1 The position of the research region

Fig. 2 Classification method based on priori rules in the region (NDVI stand for Normalized difference vegetation index; SWIR stand for Short-wave infrared; a, b, c, d, e stand for threshold, which were achieved from samples)

Fig. 3 Classification result based on decision tree rules (a: 2000 ETM classification image, b: 2007 SPOT HRG classification image)
Fig. 4: a: ETM band 5 image in 2000, b: band 5 image after data fusion, c: different image between fused band 5 and original TM band 5, d: vegetation change /non-change detection image with rules on the image difference.

Fig. 5: Vegetation change map from 2000 to 2007 in Xishuangbanna area.
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