VEGETATION COVER ANNUAL CHANGES BASED ON MODIS/TERRA NDVI IN THE THREE GORGES RESERVOIR AREA

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ABSTRACT:

Vegetation coverage change is a very important indication of the ecological enviroment change. In this paper, we detected the vegetation cover change by retrieving the fraction of the vegetation coverage, using the Normalized Difference Vegetation Index (NDVI) data from MODIS/Terra imagery in recent years from 2000 to 2006, the period before and after the Three Gorges Dam construction. In addition, the accuracy of vegetation fraction retrieval was assessed by the classification data from SPOT5 images. Based on these results, we analyzed the annual vegetation change quantitatively, and it was shown that the vegetation cover took on a little increase in the Three Gorges Reservoir Area in recent seven years, and the vegetation cover grades was transforming from low coverage to high coverage.

1. INTRODUCTION

Along with the construction of the Three Gorges' dam and hydropower station, the eco-environment in the Three Gorges Reservoir Area has been given full attention by local government and scientific community. The main potential environmental problem such as Land use and land cover changes (LUCC), water pollution, geological disasters, soil erosion, and the subsequent impact on the microclimate and biodiversity, have been recognized. In which, LUCC has been considered as one of the dominant causes of ecological environment changes, and that vegetation cover changes are one of the important components of LUCC (Zhang, 2008). In the Three Gorges Reservoir Area, the vegetation cover is changing year by year. The project constructed, emigration moving and factories built made the vegetation cover reducing, and moreover, some retrieval policies such as enclosing the hills for natural afforestation, and conversion from cropland to forest, brought an increase in vegetation cover. Therefore, the researches on change detection and change assessment of vegetation, as well as subsequent impact on environment are necessary for future regional planning and governmental policy-making. Here we used NDVI data from MODIS/Terra sensor to retrieve the fraction of vegetation coverage, obtaining and analyzing the recent vegetation cover changes in the Three Gorges Reservoir Area from 2000 to 2006.

2. STUDY AREA

The Three Gorges Reservoir Area (TGRA) locates at latitude 28°56′N-31°44′N and longitude 106°16′E -111°28′E, central China (Fig.1), lower section of the upper reaches of the Yangtze River at the boundary of Sichuan and Hubei with the area of 58 000 square kilometers and with the population of almost 20 million (Meng, 2005). The TGRA consists of submerged portions at 175 meters water level and resettlement area involved in 21 counties and cities of Chongqing city and Hubei province, which stretches along the Yangtze River fom Jiangjin City to Yichang City (Zhang, 2008). The reservoir area is very narrow and where the geography is complex. The mountainous areas represent 74% of the region only with 4.3% plain area in the river valley and 21.7% hilly area. Sloping lands of the gradients greater than 5 degree are accounting for 90 percent in the whole fields, and the average slope value is more than 25 degree. The climate of the Three Gorges Reservoir Area is the subtropical monsoon climate. The vegetation are abundant and various, but self-sown plants are reducing instead of manual plants in farming area, because of a long reclaiming history. Compared to farming area, the self-sown vegetation are more in woodland area, however, the area and types are reducing quickly because of the over-felling, as a result, water and soil erosion in some area are serious. Moreover, the increasing population is destroying the natural plants continuously, and the slope croplands are reclaimed severely.

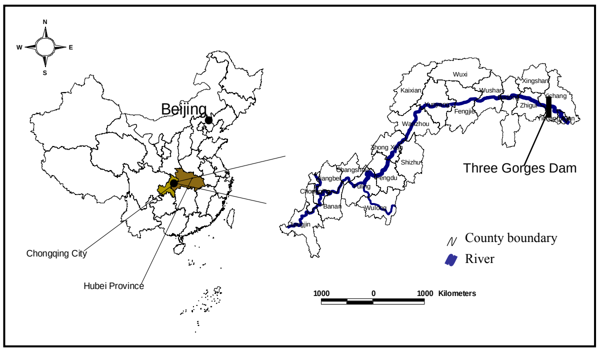

Figure1 . Location of study area

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3. DATA AND METHOD

3.1 Available datasets

The dataset we used in this study is MODIS 16-day composite NDVI time series data provided by the Data Center, United States Earth Resources Observation System (Earth Observation System, EROS). The spatial resolution is 250 meters. The data were acquired in its vegetation growing season, from April to October extending from 2000 to 2006, which can better reflect the vegetation growth and changes. Geometric correction and the band image calibration were performed as early processing step in this research.

The land use/land cover map of Kai County for 2000 was provided by the Chinese Academy of Surveying and Mapping, which was classified from SPOT5 images with the resolution of 2.5m by manual interpretation (Fig.2b). This classification map was used as reference data to assess the accuracy of the fraction of vegetation cover (FVC) retrieval in our study.

3.2 Data preprocessing

The image datasets were preprocessed including the maximum value composite (MVC) and cloud removed. To reduce the image noises from the atmospheric clouds, particles, shadows, etc, we synthesized two 16-day composite NDVI images to one 32-day composite NDVI image in sequence by using the MVC method (Ding, 2006）. At the same time, monthly NDVI images were obtained.

Although the MVC method reduce the impacts form the atmospheric clouds, particles, etc., there are still clouds pollution. Therefore, to solve the problem, the composite images are processed using the best index slope extraction (BISE) methods (Wang, 2005).

$$dNDVI_{t-1,t} = \frac{(NDVI_{t-1} - NDVI_t)}{NDVI_{t-1}} \times 100\% \qquad (1)$$

$$dNDVI_{t,t+1} = \frac{(NDVI_{t+1} - NDVI_t)}{NDVI_{t+1}} \times 100\% \qquad (2)$$

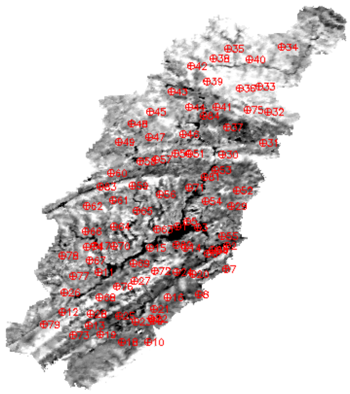
where NDVIt-1 and NDVIt+1 denote the NDVI values of time t-1 and t respectively; dNDVIt-1,t and dNDVIt,t+1 show the variation rate from t-1 to t and from t+1 to t respectively. It is assumed that the pixel at time t is affected by clouds if dNDVIt-1,t and dNDVIt,t+1 are both surpass 20%, then the t time pixel value is corrected by the average of time t-1 and time t+1. We applied the algorithm to detect the contaminated position point and smooth the NDVI time series data for all the pixels in our study periods excluding the starting and ending points. For the first and end pixels, the improved BISE method is adopted: if dNDVI1,2 is more than 20%, the first pixel is substituted by the average of time 1 and time 2. The last pixel value is processed in the same way.

3.3 Retrieval of FVC

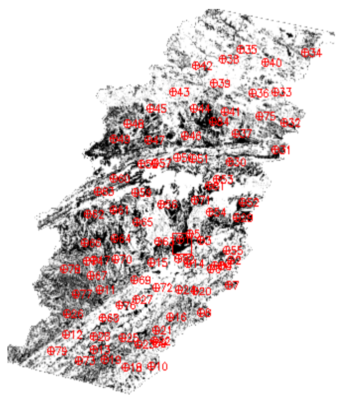
The fraction of vegetation cover (FVC) is the vertical projection of the crown or shoots area of vegetation to the ground surface in a unit area, expressed as the fraction or percentage (Guo, 2007; Purevdor, 1998). In general, Dense Vegetation Model and Non-dense Vegetation Model are the methods in common use. According to the sub-pixel structure characteristic, Dense Vegetation Model based on pixel linear decomposing was adopted in this study (Gutman, 1998). Based on the resultant monthly NDVI images, the vegetation fractions from April to October of each year are calculated. And then, annual vegetation coverage percent was achieved by averaging the seven monthly vegetation coverage data in each year, which can be used to analyze the annual change of vegetation cover.

3.4 Accuracy assessment

Field measurement of pixel points is the conventional method to estimate the accuracy of vegetation cover fraction. But in this study it was hardly to survey the vegetation cover fraction in a unit as large as 250 meter multiplied by 250 meter, so a new solution using SPOT5 classification images was adopted instead of field survey. We choose kai County as test area. Firstly, all the land use/land cover types of SPOT5 classification images with the resolution of 2.5m were divided into “vegetation” and “non-vegetation” types which were expressed as “1” and “0”, on the hypotheses of vegetation types being full vegetation coverage, and vice versa. Secondly, the vegetation and non-vegetation image was resampled with the spatial resolution of 250 meter, and each new pixel value was replaced by averaging of corresponding 10,000 sub-pixel values. The resampled image was used as real vegetation cover data (i.e. reference image) to estimate the accuracy of FVC retrieval.



(a)



(b)

Fig.2 sampling points of accuracy assessment of FVC retrieval: (a) sampling points in FVC retrieval image in 2004; (b) sampling points in classification image in 2004

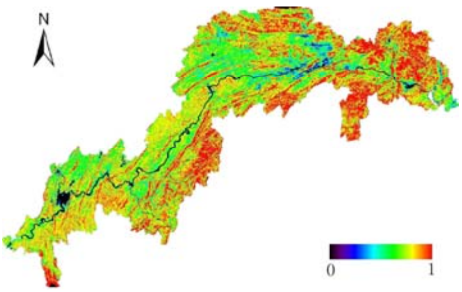
84 samples were selected from FVC image and reference image of Kai County respectively (Fig.2), and the statistic numbers of these samples were shown in Tab.1.The mean square deviation was calculated by the formula:

$$\sigma = \sqrt{\left(Vi - V_0 i\right)^2 / \left(n-1\right)} \qquad (3)$$

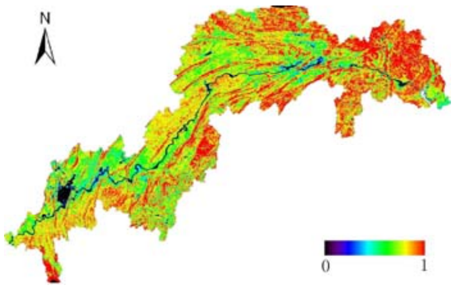
Where Vi is the retrieval value, V0i is the reference value. By this equation the mean square error was less than 17%, that is to say, FVC can be obtained from MODIS vegetation indices with accuracies lower than 83% in the TGRA.

4. RESULTS AND DISCUSSIONS

The methodology described above was applied to the NDVI data from MODIS images to create the annual FVC images from 2000 to 2006 in the TGRA. Fig. 3 showed us the retrieval images in 2000 and in 2006 (limited by paper length, the other five retrieval images were omitted). From these pictures we can see there was no obvious change in this area in our study time. To study the change between different vegetation cover types, 5 classes were divided by the threshold value of FVC images. They are no vegetation cover (NC) by FVC less than 0.2, low vegetation cover (LC) by 0.2<FVC<0.45, medium vegetation cover (MC) by 0.45<FVC<0.75, high vegetation cover (HC) by 0.75<FVC<0.9, and full vegetation cover (FC) by FVC more than 0.9.



(a)



(b)

Fig.3. Illustration of the vegetation fraction maps of the Three Gorges Reservoir Area in 2000 and in 2006: (a) Vegetation fraction map in 2000; (b) Vegetation fraction map in 2006.

4.1 Feature value change analysis of vegetation coverage

Monitoring results from Landsat TM and MODIS imagery showed us that there was no obvious change on the vegetation cover during 7 years from 2000 to 2006 in this area (see Fig. 3c and 3d), but overall trend was that there was a slight decrease in the area of cropland, woody land and grassland, compared to a little increase on the averaged vegetation cover per pixel (Tab. 1). The mean vegetation cove fraction was 0.761 in 2000 while 0.769 in 2006, with an increase of 0.8% in the seven years. Usually, the regions where there were vegetation cover changes were construction areas and the areas with rapid economic development, such as the dam area, Fengjie County, Yunyang County, Kai County, north of Fuling, middle of Chongqing city, south of Jiangjin city, etc.

Year	minimum	maximum	avergae	Mean square error
2000	0.074071	0.907299	0.761144	0.067085
2001	0.100025	0.914586	0.749200	0.070722
2002	0.065377	0.912588	0.770832	0.065433
2003	0.057644	0.930441	0.779378	0.068252
2004	0.067976	0.921937	0.783044	0.073894
2005	0.085229	0.903025	0.764458	0.072537
2006	0.096957	0.915866	0.768665	0.072578

Table 1. Feature values of FVC images from 2000 to 2006

4.2 Grade change analysis of vegetation coverage

The vegetation coverage in TGRA was being converted from NC to LC or from MC to HC (Tab. 1). The ratio of HC area was increasing with the number 68.7% in 2000 to 72.5% in 2006. The reasons are various. Increasing of water areas and construction lands caused by the Three Gorges Project construction and resettlement, reduced vegetation coverage area, however, implementation of a series of relative environment protection, such as several important forest projects of de-farming and reforestation, mountains closed for afforestation, Yangtze River Forest Protection Project, greenbelt construction in the reservoir, increased the fraction of pixel vegetation coverage.

5. CONCLUSIONS

From the results of the vegetation cover fraction retrieved from time series Modis NDVI data of the TGRA, it can be concluded that:

(1) It is proved to be effective that yearly vegetation cover information was achieved by monthly vegetation cover fraction using MODIS NDVI data from April to October.

(2) The vegetation cover was increasing in a small extent in the Three Gorges Reservoir Area in recent seven years, with the average vegetation cover fraction from 0.761 in 2000 to 0.769 in 2006. In general, the vegetation cover took on a good developing state.

(3) The vegetation cover types were transformed from NC to LC and from MC to HC. The proportion of HC was enhanced from 68.7% in 2000 to 72.5% in 2006. In a word, the vegetation cover has been improved in recent seven years.

Vegetation cover types	area（km2）							2000-2006	
	2000	2001	2002	2003	2004	2005	2006	Change area（km^2）	Change ratio（%）
NC	44.13	34.31	30.42	30.84	52.29	32.82	22.46	-21.66	-49.1%
LC	618.83	650.52	564.67	636.22	669.79	683.66	727.68	108.86	17.6%
MC	17492.27	23896.18	14517.66	10742.21	10780.84	17774.07	15186.22	-2306.05	-13.2%
HC	39834.52	33408.25	42876.47	46579.03	46483.09	39499.20	42028.78	2194.26	5.5%
FC	0.05	0.53	0.59	1.49	3.79	0.05	0.64	0.59	
Total	57989.8	57989.8	57989.8	57989.8	57989.8	57989.8	57965.8	-24.01	-0.04%

Table 2. The area of vegetation coverage grade changes in the TGRA

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