A STUDY ON FAST ESTIMATION OF VEGETATION FRACTION IN THREE GORGES EMIGRATION AREA BY USING SPOT5 IMAGERY

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ABSTRACT:

Vegetation Fraction is a comprehensive quantitative index in forest management and vegetation community cover conditions, and it's also an important parameter in many remote sensing ecological models, such as RUSLE model in soil erosion study. Traditional ground measures method to get the regional-scale vegetation fraction is very difficult due to the costs, labor and time involved. Therefore, it's meaningful to study on fast estimation of vegetation fraction from remotely sensed data. In this study, we make use of modified Gutman model to get vegetation Fraction in Three Gorges emigration area by using SPOT5 Imagery. It assumes each pixel is a mosaic pixel. The spectral information is composed of vegetation and soil spectral information. Through computing the normalized difference vegetation index (NDVI) which is sensitive to vegetation, we define the soil and vegetation threshold according to ground field data. Then, using Gutman model we get vegetation Fraction. The result shows the accuracy of this method is fine, and it is feasible in fast estimation of regional vegetation fraction.

1. INTRODUCTION

Vegetation Fraction is defined as the percentage of vegetation occupying the ground area in vertical projection. It's a comprehensive quantitative index in forest management and vegetation community cover conditions, and it's also an important parameter in many remote sensing ecological models, such as RUSLE model in soil erosion study. Changes in vegetation cover directly impact surface water and energy budgets through plant transpiration, surface albedo, emissivity, and roughness (Aman et al., 1992).

Field measurement, as a traditional method of vegetation fraction, can be divided into three kinds of methods according to principles: field sample method, instrument method and visual estimation method (Sutherland, 1999). Traditional field measurement method to get the regional-scale vegetation fraction is very difficult due to the costs, labor and time involved. Furthermore, the reliability of some field measurement methods for the vegetation fractional coverage is questionable (Curran et al, 1986). Thus, traditional method is not feasible in regional-scale estimation of vegetation fraction.

In order to get regional-scale estimation of vegetation fraction, we can utilize remote sensing data. Satellite data provides a spatially and periodic, comprehensive view of land vegetation cover. (Chen Yunhao et al, 2005). The common remote sensing method is to use empirical regression formulation or vegetation index to estimate vegetation fraction. Graetz et al. (1988) utilized the fifth band of Landsat MSS data and field data to establish empirical relationship, and estimated the vegetation fraction in semi-arid soil region. Peter (2002) used four bands of ATSR-2 remote sensing data (555nm、870nm and 1630nm) to regress separately with vegetation fraction and LAI, the result shows estimation precision using the linear mixture model with four bands is higher than single band or vegetation index. Empirical regression model can be well applied in specified district, especially with small areas. However, it needs lots of precise field data and can not be applied in other district.

Gutman and Ignatov put forward a method to get the estimation of vegetation fraction. It assumes each pixel is a mosaic pixel. The spectral information is composed of vegetation and soil spectral information. The method is fit for getting the estimation of vegetation fraction inlarge-scale region.

2. STUDY AREA

The reservoir area of the Three Gorges Project (TGP) is situated at a point 106º00'~111º50'east longitude, 29º16'~31º25'north latitude in the lower part of the upper reaches of the Yangtze. It starts from Yichang of Hubei Province and ends at Jiangjin City of Chongqing Municipality. The inundated areas affected by return currents and the places involving resettlement cover 20 counties or cities. The reservoir area covers 57,900km^2, including 9,777km^2 of cultivated land, accounting for 16.9%, averaging 0.76 mu (one mu ≈ 1/15 of a hectare).

The emigration area is part of the reservoir area. It covers 16,000km2. It is located within 10 kilometers distance from Yangtze River. The population of the emigration area is 725,500. It covers middle and low mountain valleys in Sichuan and Hubei and the low hilly areas in eastern Sichuan. There is the Daba Mountain to the north and the Yunnan-Guizhou-Guizhou Plateau to the south, with the topography tapering from west to the east.

The location of the emigration area in the reservoir area of the TGP is illustrated in Figure 1.

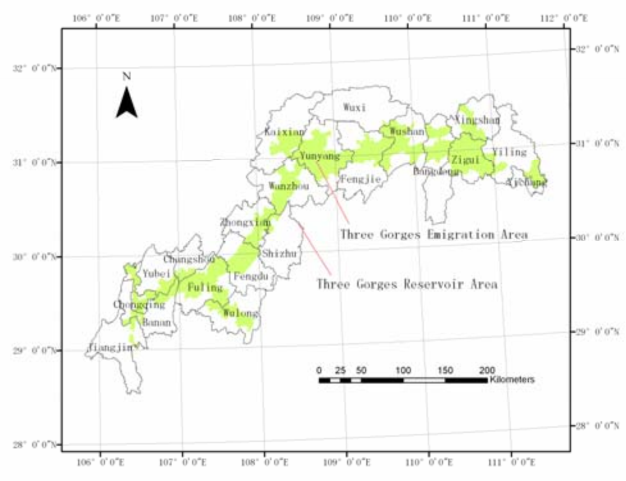


Figure 1. Study area

3. MODEL

The main objective of this study is to make use of Gutman's mosaic-pixel model to get fast Vegetation Fraction estimation in regional scale. It assumes each pixel is a mosaic pixel. The spectral information is composed of vegetation and soil spectral information. The same NDVI signal may result from different sub-pixel structures of a satellite pixel (Price 1992).

According to different combinations of horizontal and vertical densities, Gutman summarize two different models: uniform-pixel model, mosaic-pixel models. Table 1 shows the models and their applied conditions.

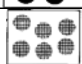
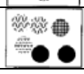
model	Vegetation density	Schematic representation
Uniform-pixel model	Uniform full vegetation	
Mosaic-pixel model	Dense vegetation	
	Nondense vegetation	
	Variable density vegetation	

Table 1. Schematic representation of models

When it is uniform full vegetation, vegetation fraction is 100%, and it conforms modified Beer's law:

$$NDVI = NDVI_{\infty} - (NDVI_{\infty} - NDVI_0)\exp(-kL_g) \quad ①$$

When it is dense vegetation :

$$NDVI = f_g NDVI_{\infty} + (1 - f_g)NDVI_0 \quad ②$$

When it is non-dense vegetation:

$$NDVI = f_g NDVI_g + (1 - f_g)NDVI_0 \quad ③$$

When it is variable density:

$$NDVI = \sum f_{gi} NDVI_{gi} + (1 - \sum f_{gi})NDVI_0 \quad ④$$

L_g is the leaf area Index and k is the extinction coefficient. $NDVI_0$ and $NDVI_{\infty}$, are the signals from bare soil (Lg->0) and dense green vegetation (Lg->∞) respectively. F_g is the vegetation fraction.

Uniform-pixel model is a model in ideal condition. In this model, vegetation fraction is 100%. NDVI is determined by leaf area index. Thus, we can only choose mosaic-pixel model.

On one hand, the study area is mainly mountainous and hilly area and the vegetation cover is well except urban area. On the other hand, extinction coefficient k and leaf area index L_g is difficult to obtain in large-scale region , and the precision of k and L_g will limit final vegetation fraction precision. Considering the two aspects, we make use of mosaic-pixel model in dense vegetation condition as the approximate calculation model of vegetation fraction in vegetation cover area. In non-vegetation cover area, the vegetation fraction is zero. Land use classification map is used to distinguish vegetation and non-vegetation area.

Formulation ② is transformed to formulation ⑤ as follows to get fg.

$$f_g = \frac{NDVI - NDVI_0}{NDVI_{\infty} - NDVI_0} \quad ⑤$$

4. METHODOLOGY

The flowchart for the vegetation fraction is illustrated in Figure 2.

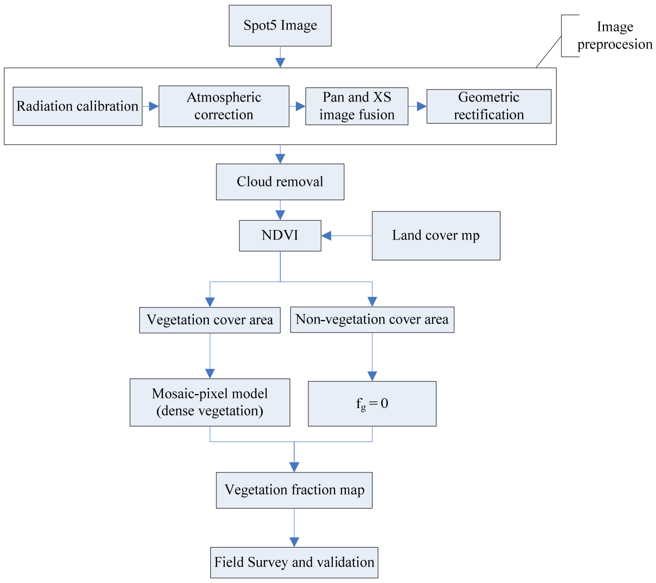


Figure 2. Flowchart for vegetation fraction estimation

4.1 image preprocess

Image preprocess includes radiation calibration, atmospheric correction, image fusion and geometric rectification.

Raw images record the Digital number (DN). In order to get accurate normalized difference vegetation index (NDVI), we should transform DN value to reflectivity. After radiation calibration, we can get the image reflectivity.

Because of atmospheric condition's difference in horizon, it forms satellite signal's difference caused by atmosphere scattering and atmosphere absorption. Thus, we should eliminate atmospheric effect. In support of Erdas ATCOR2 module, we input image acquisition date, solar zenith, ground elevation, visibility and other related parameters, and carry out atmospheric correction.

Then, we utilize 10m multi-spectral bands image and 2.5m panchromatic to carry out geometric rectification each other. The accuracy is less than 1 pixel. The next is to determine image fusion method. We compare principal component analysis (PCA) method, multiplicative method, brovey transform method and wavelet transformation method, etc. Finally, we choose principal component analysis (PCA) method. It is the optimal method and can meet the need of correct NDVI calculation. It can not only sharp the image to 2.5m, and keep the original multi-spectral reflectivity. Other methods will result in that there are noises in fusion images or it changes spectral values.

Finally, image-to-map geometric rectification was carried out using 1:10000 topographic maps. Geometric accuracy is less than 1 pixel. The project is Gauss Kruger (Spheriod: Krasovsky; Central meridian: 108° ; False easting: 500000 meters).

4.2 Cloud Removal

In Three Gorges Reservoir, clear sky is hard to see. Thus, it is almost impossible to get cloudless SPOT5 images in the regional-scale. It is necessary to mark cloud areas and replace these areas using other SPOT5 images or TM images. The precondition is that the acquisition date of those SPOT5 images or TM images is close with original SPOT5 images.

4.3 land cover classification and mask

NDVI is usually sensitive to vegetation. However, NDVI of Some special features will be abnormal. These features includes roof made of different material such as aluminium, road with special materials, etc. The NDVI of those features is similar with vegetation. Thus, it is difficult to identify vegetation and non-vegetation areas only using NDVI, and land cover classification map is needed.

Land cover classification map is used to identify vegetation areas and non-vegetation areas. Correspondingly, the mask file is produced. The method of land cover classification is object-oriented. The land use classification system adopts modified FAO land use classification system. In support of Ecognition Software, we carry out image segmentation. Through different feature indices, such as spectral mean, NDVI, SAVI, etc, we set up feature space. Those indices is sensitive to different features. Based on those, we produced basic land cover classification map. Then, using some field samples, we modified the land cover classification results manually. Using other field samples, we made validation and accuracy evaluation. The result shows accuracy of land cover classification is as high as 95%.

4.4 vegetation fraction estimation

mosaic-pixel model in dense vegetation condition is selected to estimate vegetation fraction. According to formulation ⑤,

$$f_g = \frac{NDVI - NDVI_0}{NDVI_\infty - NDVI_0} .$$

We need to calculate NDVI. NDVI is defined as follows:

$$NDVI = \frac{B_{nir} - B_r}{B_{nir} + B_r} \quad ⑥$$

NDVI is scaled to [0,255]. Scaled NDVI will enhance image display effect and will save disk space.

Then, NDVI0 and NDVI∞ should be determined. Both NDVI0 and NDVI∞ are constant. But the NDVI0 and NDVI∞ are different between different SPOT5 scenes. We should find bare soil endmember and dense vegetation endmember in each SPOT5 scenes. NDVI0 and NDVI∞ in each SPOT 5.

5. RESULTS AND DISCUSSION

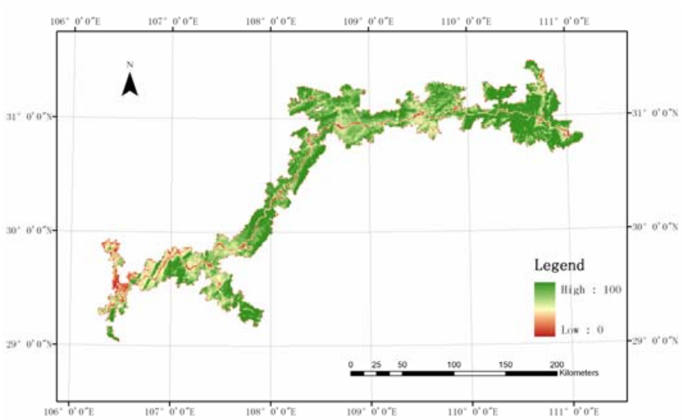


Figure 3. Estimated vegetation fraction map

The vegetation fraction estimation result (Figure 3) shows that the vegetation fraction in the west of study area and the areas along Yangtze River are relatively lower than other areas. The reason is that Chongqing city locates in the west of study area, it is the most important city in the west of China. The areas along Yangtze River is agreeable for human being survival and development, human being activity results in the vegetation fraction of these areas is lower and lower. The other areas is mainly mountainous areas, residential area is sparsely distributed in these areas, and less human being activity makes forest in these areas in good condition.

Next, we analyze the accuracy of vegetation fraction estimation quantitatively. Field survey was carried out in September, 2006 and September, 2007. Some abnormal samples were eliminated and 19 valid Samples patches were selected to evaluate the accuracy of vegetation fraction estimation, which includes different land-cover type, such as conifer forests, broadleaf forests, cropland, shrub, grassland, water body, urban construction. These samples are randomly, proportionally distributed in the study area. The result of accuracy analysis is listed in Table 2.

ID	land cover type	Obs.	Est	Abs.	Rel.
1	cropland	61	54	7	11%
2	broadleaf forest	40	38	2	5%
3	broadleaf forest	68	61	7	10%
4	shrub	50	44	6	12%
5	Water body	0	0	0	0
6	shrub	46	41	5	11%
7	conifer forest	55	57	2	4%
8	cropland	100	91	9	9%
9	conifer forest	80	74	6	8%
10	Broadleaf	32	26	6	19%
11	conifer forest	70	69	1	1%
12	Grass land	61	64	3	5%
13	Shrub	71	62	9	13%
14	broadleaf forest	45	48	3	7%
15	conifer forest	50	55	5	10%
16	Grass land	70	67	3	4%
17	conifer forest	61	55	6	10%
18	Grass land	19	21	2	10%
19	conifer forest	58	65	7	12%
20	urban construction	0	0	0	0
Avg. error					8%
Avg. accuracy					92%

Table2. Accuracy estimation of estimated vegetation fraction (Obs. Observation value, Est estimation value, Abs. absolute error, Rel.relative error, Avg.error, average error, Avg. accuracy, average accuracy)

The analysis of accuracy estimation (Table 2.) shows vegetation fraction estimation result is fine, the average accuracy is up to 92%. The method of vegetation fraction estimation is feasible in large-scale region. Scattergram of observation and estimation (Figure 4.) was produced and linear regression was carried out. Estimation value is highly related with observation (R^2=0.96, n=20).

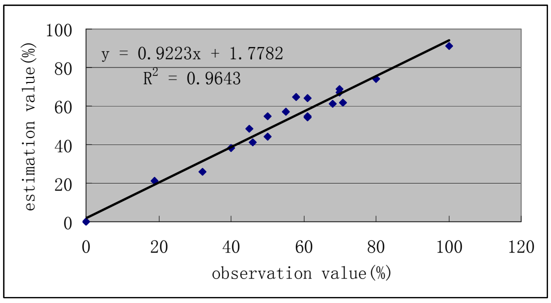


Figure 4. Estimation value Vs. observation value

6. CONCLUSION

In this study, we use Gutman model combing with land cover map to get vegetation cover estimation in Three Gorges emigration area. It assumes each pixel is a mosaic pixel. The spectral information is composed of vegetation and soil spectral information. The accuracy of estimation is fine, general accuracy is up to 92%. The method is feasible to get fast estimation of vegetation fraction in large-scale region. The accuracy of land cover map and image fusion will effect the accuracy of vegetation fraction estimation in some degree.

REFERENCE

Adams, J. B., Smith, M. O., & Johnson, P. E. (1986). Spectral mixture modelling: A new analysis of rock and soil types at the Viking Lander 1 site. Journal of Geophysical Research, 91, 8089−9012

Sutherland W J. Zhang J-T trans.1997 Manual of Survey Method in Ecology. Beijing: Science and Technology Literature Press

Curran P J, Williamson H D. 1986. Sample size for ground and remotely sensed data. Remote Sense of Environment, 20:31-41

Gutman, G., Ignatov, A., 1998. The derivation of the green vegetation fraction from NOAA/AVHRR data for use in numerical weather prediction models. International Journal of Remoete Sensing 19, 1533-1543

Calera, A., Martinez, C., Melia, J., 2001. A procedure for obtaining green plant cover: relation to NDVI in a case study for barley. International Journal of Remote Sensing 22, 3357-3362.

Chen, J., Chen, Y., He, C., Shi, P., 2001. Sub-pixel model for vegetation fraction estimation based on land cover classification. Journal of Remote Sensing 5, 416-422

Foody, G.M., Cox, D.P., 1994. Sub-pixel land cover composition estimatin using a linear mixture model and fuzzy membership functions. International Journal of Remote Sensing 15, 619-631

Price, J.C., 1992 Estimating vegetation amount from visible and near infrared reflectance. Remote Sensing of Environment 41, 29-34

Price, J.C., 1993. Estimating leaf area index from satellite data. IEEE Transactions on Geoscience and Remote Sensing 31, 727-734

Quarmby, N.A, Townshend, J.R.G., Settle, J.J., 1992. Linear mixture modelling applied to AHVRR data for crop area estimation. International Journal of Remote Sensing 13, 415-425

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