Monitoring Forest Dynamics(1988-2010) in Changting County Using Time Series of Remote Sensing Data

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***Abstract*— Forest dynamics of Changting County was studied using time series of remote sensing data. MODIS 1 km 16days NDVI (MOD13A2)time series covers 2000-2010 were firstly used to detect large patches of abrupt changes by algorithm called BFAST(detecting and characterizing Breaks For Additive Seasonal and Trend).The time of the detected breaks were compared with forest disturbance map produced by visual interpretation of Landsat time series. The result showed that both commission error and omission of were high. The coarse resolution of the product, poor quality of residual cloudy pixels, noises, affects the performance of the algorithm. With 30m spatial resolution, Landsat time series were more suitable to capture forest disturbance at small scale at biennial interval, but the acquisition date differ greatly between different years, which complicated the detection. To quantify seasonal variation between different Landsat data, adaptive Savitzky-Golay filtering was applied on MODIS NDVI to denoise and extract seasonality parameters. Key seasonality parameters, such as the amplitude of growing was extracted. Which help to judge whether the breaks were affected by seasonal variation or not.. Integrated forest z-score(IFZ) was calculated for each Landsat data and vegetation change tracker were used to detect forest disturbance. The disturbance map showed that most disturbance located in central and southwest parts, and happened in 1991,1998 and 2010. Sen's Slope calculation and Mann-kendall test for undisturbed area showed that forest in east increased and declined patches distributed equally. Validation of the disturbance map and regularization of time series are necessary to improve the result.**

***Keywords*—Forest Dynamics, Time Series, Integrated forest z-score (IFZ), Disturbance, Trend**

I. Introduction

Understanding forest dynamics over space and time is crucial to ecological study Recent study[1-3] show that time series remote sensing data was able to capture forest changes at different spatial and different frequency. Besides widely used MODIS time series, Landsat time series are used widely since 2008.

In order to locate and time change quickly, we adapt a two-step plan. Firstly, MODIS 1km 16days NDVI products were used to locate large patches happening abrupt change at high frequency or showing obvious trend over long period. secondly, 30m resolution Landsat time series were used to locate the change at finer scale with longer history but with lower frequency.

II. Data Sources

Changting County was choosed as study area. The spatial extend of Changting County is Lat: 25°18′40″～26°02′05″,Lon: 116°00′45″～116°39′20″. The center part of the county is residential area and cultivated land. Area around this area are mainly forest land. Trees were planted widely to improve the ecological condition for water soil management reason, among trees planted, Pinus massoniana are pioneer species because they are more adapted to local soil barren environment, red bayberry, *Lespedeza bicolor Turcz, PaspalumwettsteiniiHackel* were also planted.

A. MODIS 16-day 1km NDVI

MODIS 16-day NDVI products from collection 5, (MOD13A2) tiled h28v06 covered the period from 01-Jan-2001 to 2-Oct-2012 were collected, reprojected and subset for further information extraction. The study period consists of 247 MODIS compositing periods

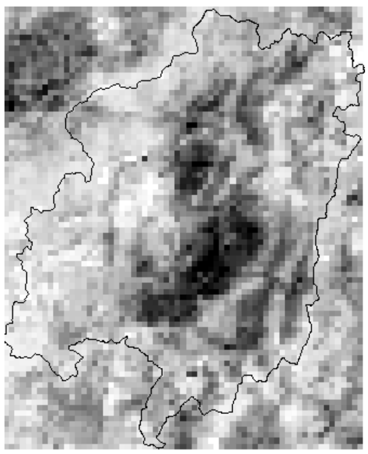

Fig. 1 MODIS 1km 16days NDVI coering Changting County

B. *Landsat TM/ETM*

Altogether 11 Landsat TM/ETM from 1988 to 2010 were used. Most of the Landsat TM/ETM were acquired in autumn, a few were acquired in winter.

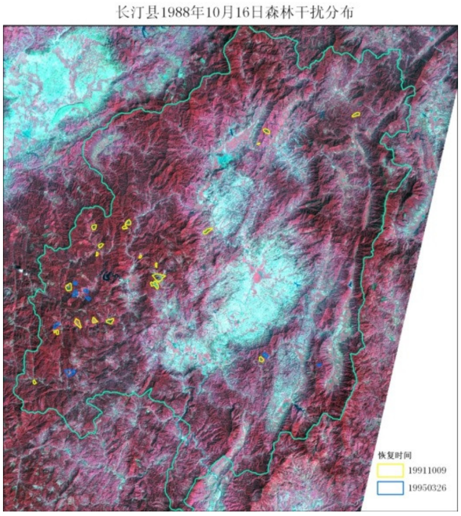

Fig. 2 Landsat TM on Oct 16,1988 coering Changting County

TABLE I

LANDSAT TM/ETM USED

1	19881016
2	19911009
3	19981113
4	20011231
5	20041012
6	20061103
7	20061221
8	20081210
9	20090111
10	20091026
11	20101029

III. .PROCESS, APPLIED METHODS

A. *Change detection for MODIS time series*

Detecting and characterizing Breaks For Additive Seasonal and Trend(BFAST)[4] were used to detect abrupt change and trend in MODIS time series. The main idea of BFAST was to decompose the original time series into trend, seasonal, and remainder components(Fig 3).From Yt, Tt, St, et symbolized original, trend, seansonal, remainder time serial respectively. From St, seasonal variation was obvious, the magnitude is about 0.25. Three breaks existed in trend component, NDVI value after first break increased rapidly the keep stable for longtime to an average level at 0.6, NDVI value after the second break increased rapidly and decreased to 0.6, NDVI value after third breaks decreased about 0.2 and increased to 0.6, this break can be explained by the disturbance event followed by recovery. From the et components, poor quality caused by residual cloudy pixels, noises, affects the performance of the algorithm, at many cases, the magnitude of the reminder component were more higher than the breaks in trend or seasonal variation.

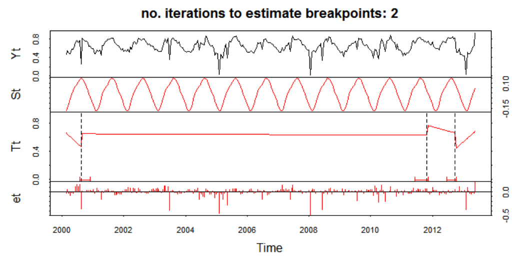

Fig. 3 decomposing of original time series by BFAST

We check time of main breaks by BFAST on MODIS time series (MTS) and visual interpretation on Landsat time series (LTS) by overlaying both, symbolizing time with same colour system and with different style. Solid pixels were result by MTS, hollowed polygons were result by LTS, both matched when the polygons overlay the solid pixels were same colour. From Fig.4, the probability of consistency was very low. Commission error and omission of were high.

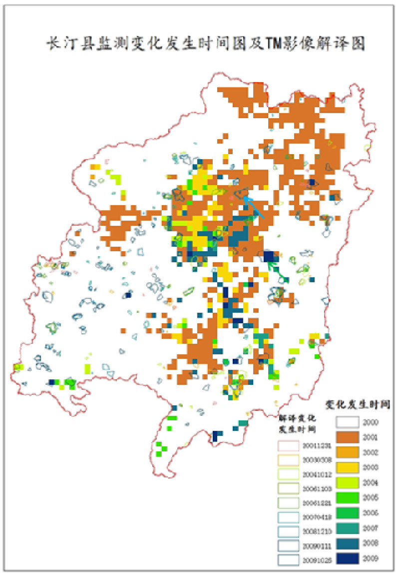

Fig. 4 time of main breaks

by BFAST on MTS(solid) and visual interpretation on LTS(hollow)

As Watts,et al(2013)[5] claimed, user-defined parameters had effect on the timing and number of abrupt changes it detect. To improve the result, parameters such as h, number of breaks were tuned, and result seem to be better as Fig.5 showed. Large patches of breaks in 2001 diminished, commission errors was decreased, map of breaks time seem to be more reasonable. Excluding breaks in the central cultivated area, breaks of forested area, especially those separate patches of change is more reliable, in these areas, breaks can be seen both from Fig.4 and Fig.5. The omission errors may be caused by the coarse resolution of MODIS data, which were not suitable to capture small patches of breaks caused by human activity.

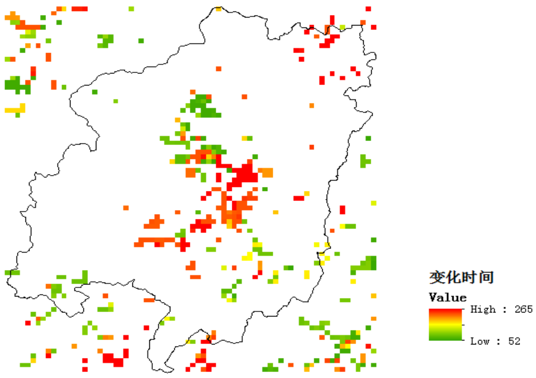

Fig. 5 time of main breaks

by BFAST with parameter tuning

With 30m spatial resolution, Landsat time series were more suitable to capture forest disturbance at small scale at biennial interval, but the acquisition date differ greatly between different years, which complicated the detection.To quantify seasonal variation between different Landsat data, adaptive Savitzky-Golay filtering was applied on MODIS NDVI to denoise and extract seasonality parameters. Key seasonality parameter, such as amplitude(Fig.6) of growing seanson was extracted and analysed. Which help to judge whether the breaks were affected by seasonal variation or not. From Fig.6, amplitude of most vegetation growing season were below 0.3 about half of the average NDVI, if breaks detected higher than this value, evidence of breaks was enough. Considering autumn is ideal season for image acquisition, images in autumn are preferred, if no autumn image in some year, images in winter was used as substitution.

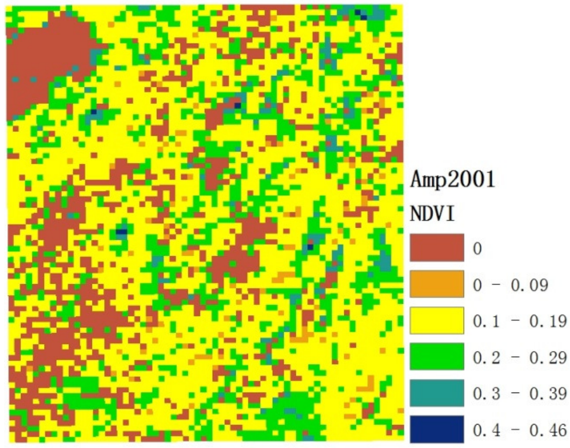

Fig. 6 Amplitude of growing season from MTS

B. Change detection for Landsat TM/ETM time series

By BFAST algorithm, changes in MODIS NDVI may caused by cultivated vegetation or forest, It's hard to distinguish between these two types of change. Huang, et al(2010)[6] adopted a parameter called integrated forest z-score (IFZ) to describe the likelihood a pixel being forest. The formula to calculated IFZ is listed as equation (1~2):

$$FZ_i = \frac{b_i - \overline{b_i}}{SD_i} (i = 3,5,7) \quad (1)$$

$$IFZ = \sqrt{\frac{1}{NB}\sum_{i=1}^{NB}(FZ_i)^2} \quad (2)$$

In equation (1), i means band order, b_i is DN value of band i of the pixel, $\overline{b_i}$, SD_i is mean and standard derivation of forest sample in band i, FZ_i is forest score of band i. Band 3,band 5,band 7, i.e., the red , two SWIR bands is used to calculate individual forest score. In equation (2), NB means the number of bands, in this case , NB = 3. IFZ is square root mean of the three FZ_i. To calculate *IFZ*, forest samples is collected from each image to calculate corresponding $\overline{b_i}$, SD_i . *IFZ* measure the degree of a pixel deviate from the forest samples, that is the lower the *IFZ,* the higher likelihood to forest sample. For forest samples, *IFZ* value is lower than other land cover types. In Fig.7, forest land is dark, residual area is bright, and cultivated land is grey.

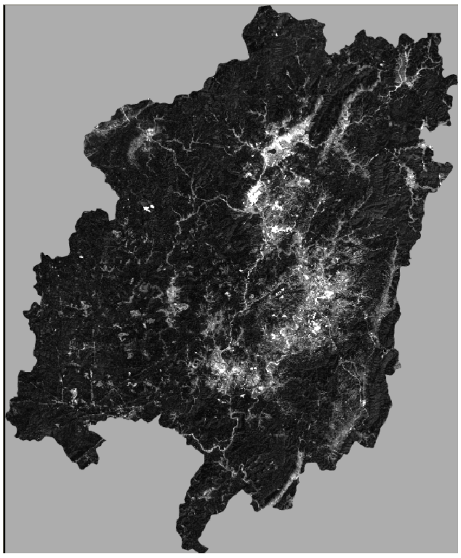

Fig. 7 IFZ image

To determine the threshold for forest, statistics on *IFZ* for forest polygon samples is carried out. From Tab. V, mean IFZ value scale is 0.8 to 0.9, standard derivations of IFZ are about 0.5, that means for most forest pixels, IFZ value will be fall in the scale 0~2. Most sample with max value below 5, but some higher than 10. In order to balance the commission error and omission error, the value of 3 is set to be the threshold to differentiate between forest and other land cover type. IFZ value greater or equal to 3 is considered as HIGH IFZ pixel, denoted HIFZ, and IFZ value less than 3 is considered as LOW IFZ, denoted LIFZ

TABLE II

STATISTICS ON IFZ FOR FOREST SAMPLES

Image date	ifzmin	ifzmax	ifzmean	ifzstd
19881016	0.076	11.016	0.835	0.551
19911009	0.066	4.384	0.85	0.517
19981113	0.065	3.914	0.863	0.504
20011231	0.02	4.087	0.862	0.507
20041012	0.139	3.578	0.899	0.438
20061103	0.091	4.159	0.877	0.48
20061221	0.027	4.858	0.862	0.506
20081210	0.092	4.221	0.865	0.501
20090111	0.057	4.761	0.853	0.521
20091026	0.079	4.393	0.862	0.507
20101029	0.091	4.528	0.858	0.514

Temporal profile for 28 forest samples being disturbed in Oct 16,1988 confirmed (Fig.8) the fact when being disturbed, most forest samples' IFZ value is above 3, some got to 6, but a few is around 2, descend in the following 3~5 years, being stable at 1.5 to 2. IFZ temporal variation will help to monitoring forest dynamics.

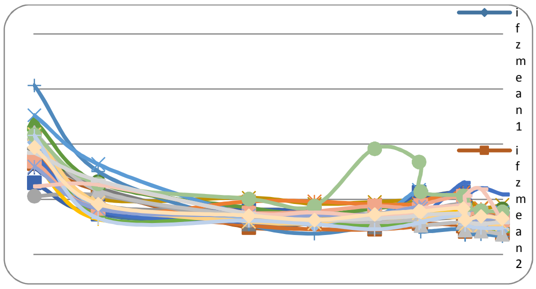

Fig. 8 IFZ temporal profile for forest samples being disturbed

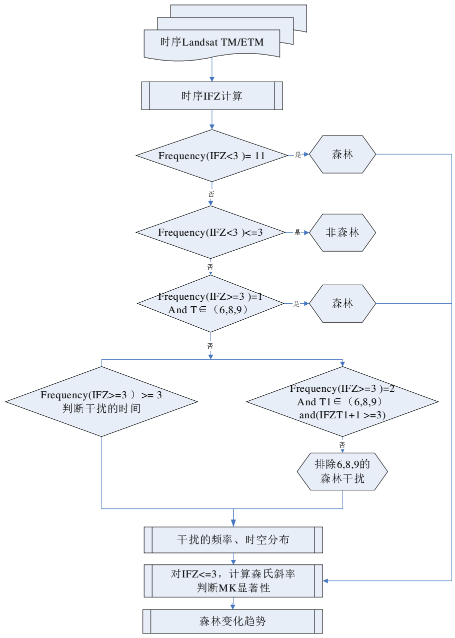

Fig. 9 forest dynamics monitoring based on temporal Landsat IFZ

A flowchart for forest dynamics monitoring was put forward based on temporal variation of IFZ. It contain following steps:

1. Time series Landsat TM/ETM data as input.

2 IFZ calculation for each image and layer stack by date order.

3. calculate frequency of LIFZ. If the frequncy equal to 11, the pixel is classified as forest. If the frequency is less than 3, the pixel is classified as nonforest.

4. Calculate frequency of HIFZ. If the frequency equal to 1, considering the fact that forest will not be recovered in less than one year, pixels with HIFZ in Nov 3,2006 and LIFZ in Dec 21,2006, or HIFZ in Dec 10,2008 and LIFZ in Jan 11,2009, or HIFZ in Jan 11,2009 and LIFZ in Oct 26,2009 would not be classified as disturbance, count the disturbance frequency, and date the start of each disturbance.

5. For pixels classified as forest, calculate Sen's Slope and carried Mann Kendall test, to determine area with significant trends.

From Fig.10, disturbance happened mostly in south west, areas around resident area.

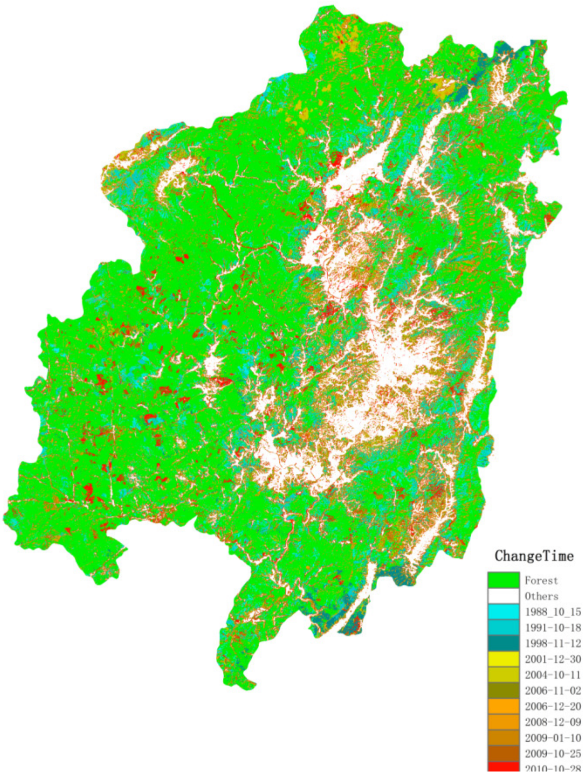

Fig. 10 Distribution of Changting County's forest disturbance

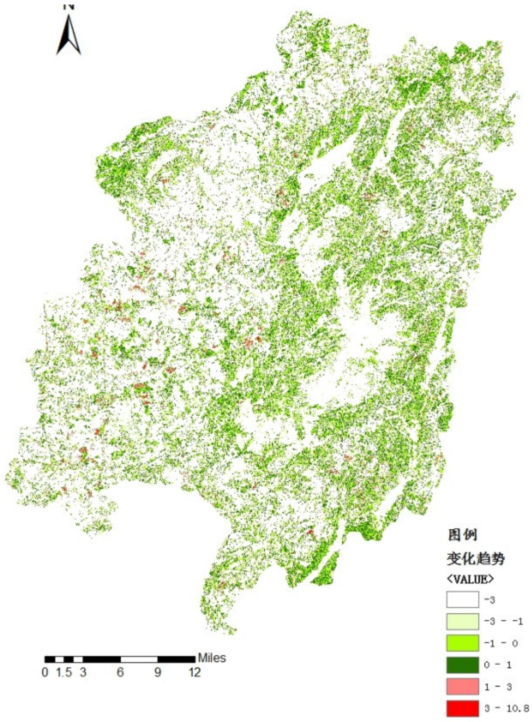

Fig. 12 Distribution of Changting County's forest trend

From Fig.11, disturbance happened more often in area around the resident area.

As Fig.12 shown, forest in the central, northwest, southeast part of Changting county recovered, forest in southwest part of the county declined. More forest in recovery than in declination.

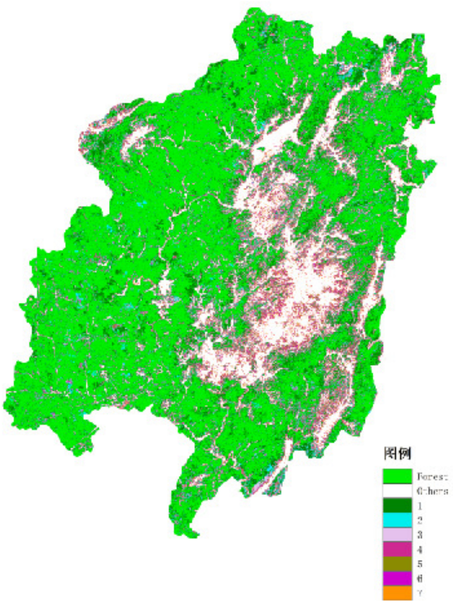

Fig. 11 Distribution of Changting County's forest disturbance frequency

IV. Conclusions

Two different type of time series data ,including MODIS 16-day 1km NDVI products from collection 5 (MOD13A2), and Landsat TM/ETM 30m data were used in forest dynamics monitoring in Changting county. BFAST and VCT algorithm were carried out on MODIS and Landsat TM/ETM time series respectively. BFAST result show that the algorithm is more sensitive to user defined parameter, and MODIS 1km data was too coarse for human induced disturbance detection. Using temporal variation of integrated forest z-score, VCT is more capable to capture disturbance in Changting county, which located mostly in south west, areas around resident area, happened more often in area around the resident area. Trend showed that more forest in recovery than in declination.

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