Determination of paddy rice growth indicators with MODIS data and ground-based measurements of LAI

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***Abstract*—The study is about the monitoring index of the growth of paddy rice with remote sensing in use of MODIS data in 2010, drawing 4 vegetation indices, ration vegetation index (RVI) 、 normalized difference vegetation index (NDVI) 、 vegetation condition index (VCI) and enhanced vegetation index (EVI) as remote sensing parameters. The vegetation indexes were selected to inverse LAI and vegetation index of LAI model was established .The study showed, among the vegetation index of LAI models, EVI and NDVI had significant correlations with LAI. The analysis of precision and accuracy using predicted value and actual value showed Cubic model of EVI was superior to the other vegetation and models, so that EVI was chosen as the final monitoring index for monitoring the growth**.

***Index Terms*—MODIS, paddy rice, vegetation index, LAI, growth indicator**

I. INTRODUCTION

Paddy rice is one of the major staple foods in Jiangxi Province, and a quarter of farmer income comes from rice production. Rice as one of the most important crops in Jiangxi Province, and its growing status is an important part of the food security system in Jiangxi Province. The Moderate Resolution Imaging Spectroradiometer (MODIS) may provide an advantage by providing continuous, wide-range, near-daily, moderate spatial resolution measurements optimized for crop monitoring (Running et al., 1999; Huete et al., 2002; Sinkyu et al., 2003, Peng et al., 2011). Xiao et al. (2005) and Chen et al. (2012)developed a MODIS approach to map paddy rice in southern China and South and Southeast Asia based on the relationship between NDVI, Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI) during the phonologic stage of paddy rice flooding and transplanting. The results could provide quantitative information on rice cropping areas and farming activities in previous study. However, the growth period are needed to be considered according to the measured LAI values in the field.

The purpose of this paper is to extend and adapt the MODIS based approach for the growth indicators of paddy rice. Grasp the timely and accurate; the impact of macro-dynamic rice growth monitoring techniques can understand the rice-growing conditions, soil fertility, pests and diseases, and nutritional status, thus preventing the adverse weather conditions in the rice-growing period, providing early yield assessment, and to improve the business of agro-meteorological services and horizontal.

II. MONITORING METHODS OF RICE VEGETATION INDEX

Vegetation Index refers to the surface reflectance combination of two or more within the wavelength range operation, in order to enhance a certain characteristic or details of the vegetation. The common vegetation indices are ration vegetation index (RVI) 、 normalized difference vegetation index (NDVI) 、 vegetation condition index (VCI) and enhanced vegetation index (EVI).

A. Ration vegetation index（RVI）

$$RVI = \frac{\rho_{NIR}}{\rho_{RED}} \tag{1}$$

RVI strengthens the differences of vegetation in the near infrared and infrared spectral reflectance. When the sparse vegetation covers, the RVI resolving power is weak. When the dense vegetation covers, the RVI value will grow indefinitely.

B. Normalized difference vegetation index（NDVI）

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \tag{2}$$

Because the vegetation space covers wide range and detection sensitivity of vegetation is high, the NDVI data has a comparable advantage. NDVI values range from -1 to 1, and the general zones of green vegetation range from 0.2 to 0.8. Because the index and vegetation density was positively correlated, larger NDVI values stand for the better vegetation.

C. Vegetation condition index (VCI)

$$VCI_j = \frac{NDVI_j - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}} \times 100\% \tag{3}$$

VCI is defined ratio as current NDVI with NDVI maximum and minimum at the same period of many years to reflect the same physiological period vegetation growth conditions (Kogan, 1990）

D. Enhanced vegetation index（EVI）

$$EVI = 2.5 \times \left(\frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + 6\rho_{RED} - 7.5\rho_{BLUE} + 1} \right) \tag{4}$$

To enhance the vegetation signal, the EVI was added blue band to correct the influence of soil background and aerosol scattering. The EVI improves the sensitivity of vegetation in the area of high biology, and strengthens the monitoring of vegetation by the weakening of the canopy background signal and reducing the atmospheric effects at the same time.

III. REMOTE SENSING DATA ACQUISITION AND PROCESSING

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A. MODIS data source

The study focused on mapping the spatial distribution and growth status of paddy rice using time-series MODIS data in Jiangxi Province. After selecting the standard MODIS data products available to the researchers, we used the 8-day composite MODIS Surface Reflectance Product (MOD09A1). Each 8-day composite includes estimates of surface spectral reflectance of the seven spectral bands at 500-m spatial resolution（http://modis-land.gsfc.nasa.gov/）. The 16-day composite vegetation indices Product was available in the NASA website（https://wist.echo.nasa.gov/api/）.

B. MODIS data processing

Although the 8-d composite surface reflectance products of MODIS have been strictly preprocessed to reduce the impacts of clouds, shadows, and aerosols, obviously residual noises still exist due to atmospheric effect and lasting heavy clouds in some regions. There are some processes for noise removing in time-series to obtain seasonal information, like the method of the single band layers extraction, MOSIC stitching, multi-band layers superimposed by the image platform of ERDAS IMAGINE.

The flooding and transplanting date is different in Jiangxi Province because of the difference in the planting schedules and rotations. Xiao et al. (2005; 2006) used a simple conditional expression of LSWI+0.05≥EVI or LSWI+0.05≥NDVI for paddy rice fields identification on the basis of the characteristic of paddy rice fields in the flooding and transplanting period, irrespective of the acquired date of the images, and used another expression of the EVI value reaching half of the maximum EVI value within five 8-d composites following the flooding and transplanting period as an auxiliary condition. Moreover, the non-rice area was further removed with the assistance of the digital elevation model (DEM) data and masks of cloud, snow, permanent water and evergreen vegetation (Sun et al. , 2009; Jing et al.,2013). The early rice planting area was estimated in Jiangxi Province (Fig. 1)

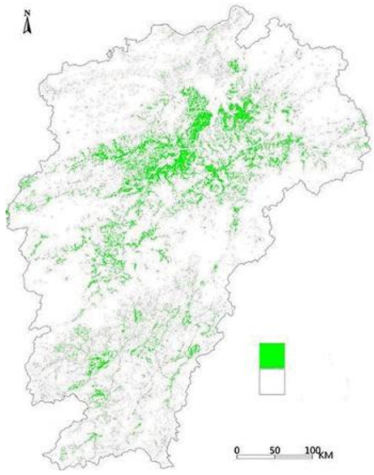

Fig.1. Distribution chart of Jiang'xi early rice planting area in 2010

IV. MONITORING INDICATORS OF RICE GROWTH BY REMOTE SENSING

A. The inversion of LAI during rice growth stage by Vegetation indices

The software for band math module of ENVI remote sensing was used to calculate the vegetation index of test points. Average vegetation index LAI was extracted by image processing platform of ERDAS IMAGINE. The determination coefficient between EVI and NDVI curve indicates the fitting degree. Among five kinds of linear Logarithmic, Quadratic, Cubic and Power model, the coefficient of determination of linear, quadratic and cubic model was greater. The two vegetation indices model are selected to do further analysis of the accuracy in order to draw the best growth monitoring indicators.

B. Accuracy analysis

The observed LAI values were used to do accuracy analysis with the inversed values. It was showed in Tab. 1. The average deviation and root mean square error for EVI Cubic curve was 0.322 and 1.226, respectively. The index was smaller than

TABLE I. ACCURACY ANALYSIS FOR LAI AND VI

VI	Model	Regression equation	RAD	ACC	RMSE
EVI	Cubic	$Y=-2.393+31.579x-62.448x^2+52.277x^3$	0.322	0.956	1.226
	Power	$Y=14.195x^{1.646}$	0.295	0.895	1.239
	Quadratic	$Y=-0.61+12.269x-3.996x^2$	0.400	0.929	1.245
	Linear	$Y=-0.169+9.308x$	0.451	0.921	1.242
NDVI	Cubic	$Y=1.55-13.32x+55.926x^2-41.014x^3$	0.450	0.83	1.351
	Quadratic	$Y=-2.724+16.415x-6.876x^2$	0.341	0.911	1.337
	Linear	$Y=-1.285+9.737x$	0.417	0.863	1.378

Note：S means relative average deviation，A means accuracy

other values and other models, and it's suitable for growth monitoring indicators for the growth of early rice.

C. Determination of paddy rice growth indicators with MODIS

EVI was deduced from the factor LAI in terms of LAI in Tab.2 as following:

$$EVI=0.152 +0.033LAI+0.019LAI^2-0.002LAI^3 \quad (5)$$

Based on agronomy survey indicators of rice growth (Table 2), the indicators range of growth monitoring of remote sensing was given in Table 3.

TABLE II. THE AGRONOMY INDICATORS OF EARLY RICE SEEDLINGS IN LEVEL 1-3

Development stage	Status	LAI		
		Average	Range	Value
Tillering stage	Level 1	0.6	0.3-0.9	＞0.5
	Level 2	0.35	0.1-0.8	0.3-0.5
	Level 3	0.28	0.2-0.4	＜0.3
Jointing stage	Level 1	5.28	3.6-7.2	＞4.5
	Level 2	3.74	2.7-5.2	3.0-4.5
	Level 3	3.24	1.0-4.6	＜3.0
Heading stage	Level 1	4.71	3.9-5.4	＞4.7
	Level 2	3.89	2.9-4.9	3.1-4.7
	Level 3	3.47	2.7-4.3	＜3.1
Milky stage	Level 1	4.04	3.0-5.5	＞4.2
	Level 2	3.52	2.6-4.1	2.8-4.2
	Level 3	2.6	2.1-3.9	＜2.8

V. CONCLUSION AND DISCUSSON

Rice vegetation index was extracted based on 2010 MODIS data source. The field survey data combined with the 11 pilot sites in Jiangxi Province in 2010, the vegetation index inversion of LAI the model was finished. The greater determination coefficient of LAI, EVI and NDVI indicates better fitting degree. Among the five kinds of linear and non-linear curve model, the coefficient of determination of the linear, quadratic and cubic model has better fitting degree. Cubic model of EVI in prediction accuracy is better than other vegetation indices and other model. EVI was selected to be as the growing monitoring indicators of remote sensing based on the investigated agronomy indicators.

Statistical analysis model is a quantitative estimation of LAI remote sensing method. There is the uncertainty of the practical application of statistical analysis model function. The less number of model parameters will lead to imperfect model. In the ground-based data acquisition process, the missing sampling points in particular growth period will cause insufficient parameters to establish one model. The different observer will cause the generation of error to a certain extent.

TABLE III. THE INDICATORS OF REMOTE SENSING FOR EARLY RICE SEEDLINGS IN LEVEL 1-3

Development stage	Status	EVI	
		Range	Value
Tillering stage	Level 1	0.164-0.196	＞0.173
	Level 2	0.155-0.189	0.164-0.173
	Level 3	0.159-0.168	＜0.164
Jointing stage	Level 1	0.424-0.628	＞0.503
	Level 2	0.340-0.556	0.368-0.503
	Level 3	0.202-0.511	＜0.368
Heading stage	Level 1	0.451-0.569	＞0.519
	Level 2	0.359-0.535	0.377-0.519
	Level 3	0.340-0.486	＜0.377
Milky stage	Level 1	0.368-0.576	＞0.478
	Level 2	0.331-0.469	0.349-0.478
	Level 3	0.287-0.451	＜0.349

ACKNOWLEDGMENT

This work was financially supported by six-industry talent peak projects in Jiangsu Province (NO. NY-038), and sponsored by Qing Lan Project in Jiangsu Province. The authors are thankful for assistance provided by the staff of Jiangxi Institute of Meteorological Sciences. We would especially like to thank the reviewer for the valuable comments and suggestions.

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