Estimation of Maize Yield in Yitong County Based on Multi-source Remote Sensing Data from 2007 to 2017

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***Abstract*—With the development of remote sensing technology, the utilizations of multi-spatial and multi-spectral resolution remote images have proved to be very important in monitoring the growth and estimating the yield of agricultural crops. The light energy utilization models using remote sensing have got the wide application because of its simple data acquisition, less parameters and capabilities for time series analysis. In this research, the yield estimation has been carried out using the net primary productivity (NPP) and the contents of soil organic matter which are obtained by Carnegie-Ames-Stanford approach (CASA) model and our proposed approach respectively. More specifically, NPP of maize in the study area from 2007 to 2017 was estimated using CASA model, and the characters of spatio-temporal variation were explored. After that, the retrieval model of the soil organic matter content was established based on the relationship analyzation between the soil organic content and NPP. The characters of spatio-temporal variation also have been explored. Then the yield of spring maize in Yitong County from 2007 to 2017 was estimated using an improved yield estimation model. Moreover, the maize harvest index and the yield of maize per unit area in the study area were obtained. Finally, the growth and development information of maize in Yitong County were comprehensively evaluated combining with these mentioned data.**

Keywords—Yitong County, CASA Model, NPP, Crop Yield, Comprehensive Evaluation

I. INTRODUCTION

As one of the important food crops in China, maize is widely cultivated. Jilin province is an important base of corn production in China. The corn planted in this area is of high yield and high quality[1]. Accurate and rapid calculation of corn yield analysis of corn growth and development is conducive to the regional government timely adjustment of scientific planting plans.

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NPP is a parameter that can help to study the growth and development of vegetation. Potter et al. created the original model of CASA on the basis of previous research[2,3]. However, CASA cannot directly measure NPP of vegetation on a regional or global scale. Coping with the wide-range measurement, people tend to obtain multi-source data by means of remote sensing and build the estimation models. Meanwhile, the development of remote sensing has enriched the means of obtaining soil organic matter content and crop yield estimation[4,5].

This paper aims to:1)calculate the NPP accumulation of maize in the research area; 2) explore the fesibility and practical application value of the inversion model of soil organic matter by using NPP annual data and ground sampling soil organic matter data; 3) estimate the yield of maize in the study area.

II. DATA AND METHOD

A. Study Region

Yitong Manchu Autonomous County (43°03'~ 44°55'N, 124°49'~ 125°46' E) is located in the west-central south of Jilin province, with an area of 2523 km^2, and the total population is nearly 450,000. The county is 76 kilometers long from east to west, 66 kilometers wide from north to south, and is composed of 12 towns and 3 townships. Agriculture of Yitong county is well developed, and the cultivated land accounts for 60% of the total land area. Agriculture is a big source of income of the county. Corn, rice and soybean are the main crops. The location of Yitong country is showed in Fig. 1.

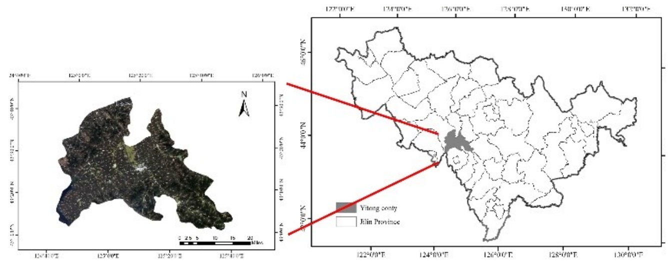


Fig. 1. Geographical location of the study area

B. Datasets

A complementary set of land-cover observations were provided by the Operational Land Imagery (OLI) and Thematic

Mapper(TM) sensors with cloudless or partly cloudy weather, from March 2007 to November 2017. HJ-1A /B satellite image data were used to supplement some periods of Landsat data which has large cloud cover. The images used in this study were downloaded from the U. S. Geological Survey (USGS) (http://earthexplorer.usgs.gov/) and the Geospatial Data Cloud (http://www.gscloud.cn/).

In addition, auxiliary data were also integrated into the estimation model. Meteorological data were provided by the China Meteorological Data Service Center of the China Meteorological Administration (http://data.cma.cn/). Statistical data were acquired from Statistical Yearbooks of China's counties and cities, which were downloaded from the National Bureau of Statistics of China (http://www.stats.gov.cn/tjsj/).

Kriging interpolation method was utilized to obtain the meteorological raster data of the research area.

C. Research Methods

NPP of spring maize in Yitong County was obtained by CASA model. NPP is estimated by using the absorbed photosynthetic active radiation (APAR), which absorbed by vegetation and the utilization efficiency of photosynthetic effective radiation (ε)[6]. APAR is the parameter determined by total solar radiation (SOL) and photosynthetically active radiation absorption ratio (FPAR) of vegetation itself. ε refers to energy fixation efficiency, and the efficiency of converting photosynthetically active radiation absorbed by plants into organic carbon. Its size is affected by vegetation types, soil moisture, temperature and precipitation. The specific calculation formula is as follows:

$$NPP(\mathrm{x},\mathrm{t}) = APAR(x,t) \times \varepsilon(x,t) \quad (1)$$

In the estimation of soil organic matter, 95 soil samples by field survey covering the study area were divided into two parts, 75 modeling samples and 20 testing samples randomly. The regression analysis was carried out by SPSS software between the content of 75 modeling samples and NPP of corresponding location points. Then, the retrieval model of soil organic matter content was established and the R^2 of the model is 0.8727.

By using soli organic matter contents and NPP, the yield estimation model for per unit area is improved based on the light energy utilization model. The parameter of this improved model consist of NPP, the conversion coefficient between plant carbon concentration and dry matter concentration, the proportion of aboveground biomass of crops compared with that of the whole plant, the water content coefficient in storage period after harvest, and the harvest index (HI) of maize. HI describes the ability that the photosynthetic assimilates convert into economic products[7]. And HI is mainly affected by the growth environment and cultivation measures. The two parameters, soil organic matter content and HI_{NDVI}, represent the growth environment and cultivation conditions of maize respectively. Finally, the performance of the model of harvest index estimation has been improved by introducing HI_{NDVI} and soil organic matter content which could be regarded as spatial distribution correction. The specific formula of corn yield per unit area estimation model is as follows:

$$Y(Yield) = \frac{NPP \times T \times p \times HI}{1-\omega} \times 10 \quad (2)$$

Where *Y(Yield)* represents the yield per unit area of maize, *HI* denotes the harvest index, *T* is the conversion coefficient between plant carbon concentration and dry matter concentration of plant. *p* represents the proportion of above-ground biomass of maize compared with that of the whole plant. ω is the moisture content coefficient of maize in the storage period after harvest, and 10 is the unit conversion coefficient.

III. Result and Analysis

A. NPP Estimation and Soil Organic Matter Inversion

Combined with remote sensing data and meteorological data, CASA model was used to calculate and obtain the annual accumulation data of maize NPP in Yitong county from 2007 to 2017, which shows an overall increasing tendency. The main variation trend can be divided into two periods. Firstly, from 2007 to 2011, the trend of NPP shows an obvious fluctuation. The second period is from 2011 to 2017. During this period, the annual average value of NPP is stable, which shows a slow increasing trend and a reduced range of fluctuation. The average annual cumulative NPP is shown in Table. 1.

TABLE I. The Average Annual Cumulative Npp

Year (year)	The average annual cumulative NPP (gC/(m2 • a))
2007	651.41
2008	883.51
2009	651.37
2010	919.02
2011	762.53
2012	791.75
2013	823.07
2014	804.47
2015	801.97
2016	810.08
2017	818.62

Through the analysis of the actual data, it can be found that the adjustment of agricultural structure is the main reason of NPP fluctuation in the first period. During this period, the cultivated area of maize in Yitong county increased significantly year by year. Because of the unstable growth and development of maize in the new planting area, the tendency of NPP is fluctuant and growing in the whole research area. After 2011, the total planted area of maize exceeded 100,000 mu, and the increase of maize species descended, so the accumulation of NPP tended to increase steadily again.

The inversion result of soil organic matter from 2007 to 2017 generally presents an upward trend. By comparing the total maize yield of Yitong county in the yearbook with the average soil organic matter content obtained by our model, the annual change trends is illustrated in Fig. 2 and Fig. 3.

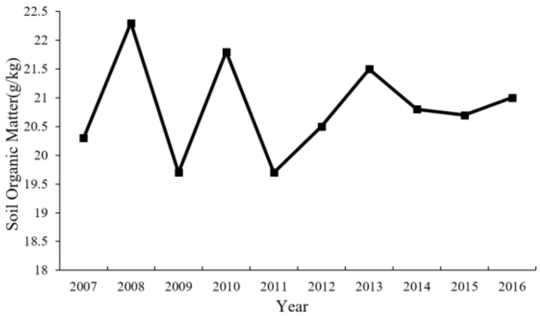


Fig. 2. The average soil organic matter content obtained by calculation of model

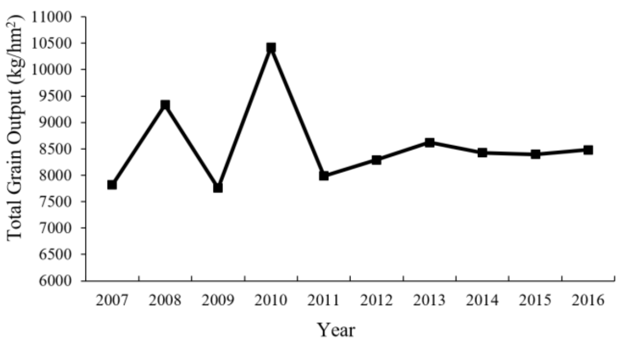


Fig. 3. The total maize yield of Yitong county in the yearbook

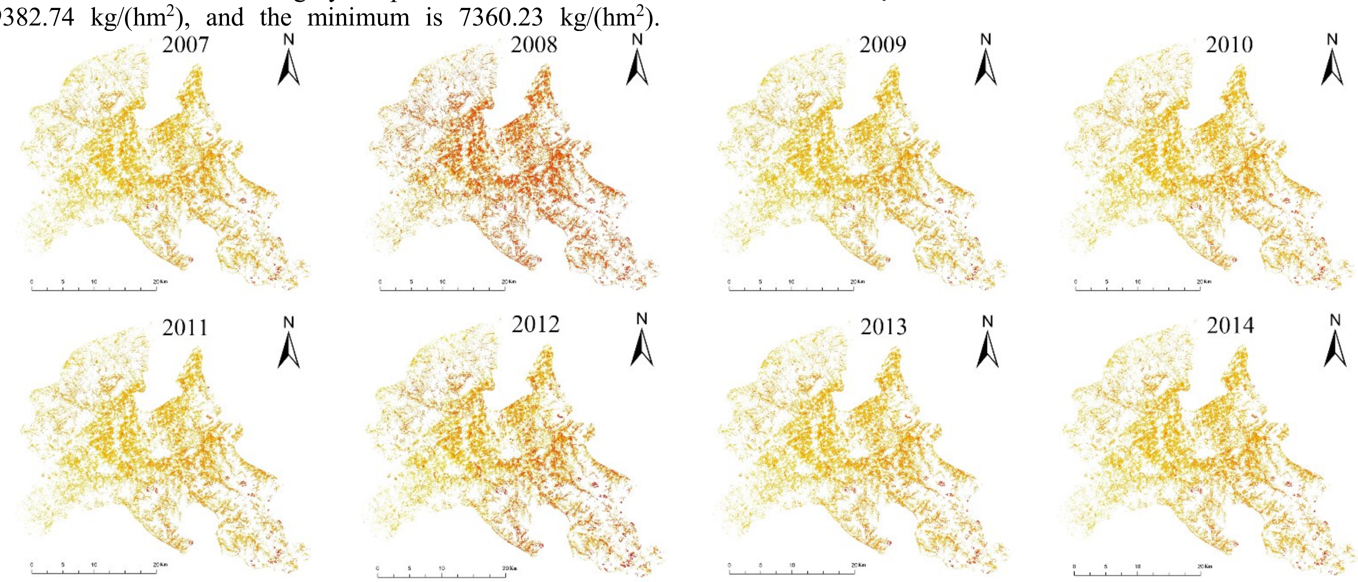
B. *Estimation of Maize Yield*

According to the annual average yield per unit area of maize from 2007 to 2017 which were calculated by the estimation model, the statistic results of maize yield per unit area over eleven years in the study area were obtained. The result are shown in the Fig. 4.

The results show that the maize yield per unit area in the study area presents an upward trend over eleven years generally. The maximum annual average yield per unit area of maize is 9382.74 kg/(hm^2), and the minimum is 7360.23 kg/(hm^2). Except for the large value in 2008 and 2010, the variation of maize yield per unit was less in the rest of the years, and maintained between 7600 and 8600 kg/(hm^2). The changing process of maize yield over eleven years can be divided into three stages on the whole. First, the maize yield showed an increase trend, up to more than 2000 kg/(hm^2) from 2007 to 2008. The second period was from 2008 to 2011, during which the maize yield showed a significant fluctuation. In the second period, the maize yield declined from 2008 to 2009 with 7800 kg/(hm^2), then increased from 2009 to 2011; During the last period from 2012 to 2017, the variation of maize yield per unit area tended to stable. Overall, there was a slight upward trend over eleven years. In the last few years, the yield per unit area of maize was stable at about 8400 kg/(hm^2). Correspondingly, it can be found that the maize planting area in the study area increased significantly from 2007 to 2011, decreased significantly after 2011 and then tended to be stable from the statistics of Yitong County, which is consistent with the results of our model. The estimated results reflect that maize planting structure was changed from big adjustment to gradual and stable growth in Yitong County over 2007 to 2017.

C. *Accuracy Verification*

Accuracy verification has been carried out to verify the reliability of the proposed estimated model. The data of statistical yearbook is utilized to verified the estimated results. It can be found that the trend of maize yield per unit in the statistical yearbook is basically consistent with that of the estimated model. The unit yield of the study area calculated by the statistical yearbook data is generally about 150-700 kg/(hm^2) which is larger than that estimated with 2%-7% relative error. Generally speaking, the estimated results of the model approximately meet the practical application requirements, and is able to represent the unit yield of maize in the study area accurately. What's more, the variation trend proves that this model has certain reliability. The research results are worth to be used for the county and municipal government departments to the analyzation of grain yield. Table 2 shows the comparison of the statistical yearbook data with the estimated results.



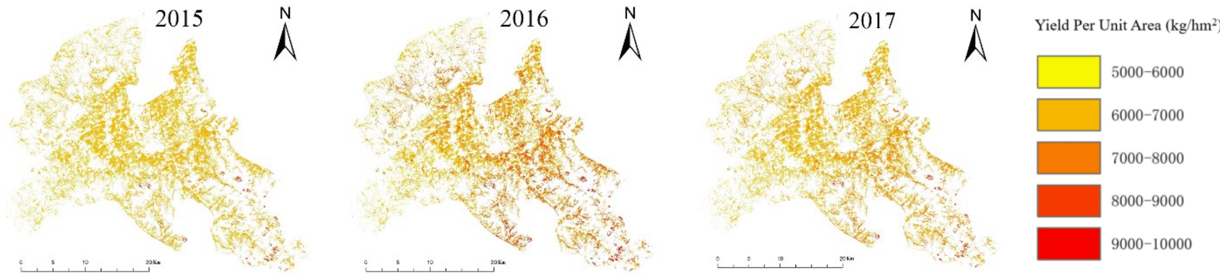


Fig. 4. The annual average yield per unit area of maize from 2007 to 2017 calculated by the estimation model

TABLE II. THE STATISTICAL YEARBOOK DATA AND THE ESTIMATED RESULTS

Year	Yearbook Data(kg/hm^2)	Yield estimation data(kg/hm^2)	Relative error	Absolute errore(kg/hm^2)
2007	7819	7628.79	2.43%	190.21
2008	9333	9122.43	2.25%	210.57
2009	7759	7664.23	1.22%	94.77
2010	10422	9682.74	7.09%	739.26
2011	7985	7770.45	2.68%	214.55
2012	8291	8044.67	3.00%	246.33
2013	8619	8412.53	2.40%	206.47
2014	8424	8252.95	2.03%	171.05
2015	8398	8217.89	2.14%	180.11
2016	8483	8324.78	1.86%	158.22
2017	-	8314.89	-	-

IV. CONCLUSION

In this paper, the annual cumulative net primary production of Maize in Yitong County from 2007 to 2017 was estimated using CASA model. It was found that the carbon sequestration of Maize is in good condition and NPP developed from fluctuant in earlier years to steady increasing in recent years. Combining with estimated NPP and soil organic matter contents which surveyed in the field, the retrieval model of soil organic matter contents was established and the soil organic matter contents of maize in the study area from 2007 to 2017 are obtained by the retrieval model. Moreover, an improved model of maize yield estimation in the study area was proposed combining NPP and soil organic matter contents. Using this model, the yield per unit area of Maize in the study area was calculated over eleven years. The average yield per unit area of maize in Yitong County was estimated to be about 8026.92 kg/hm2. Comparing with the values from Statistical Yearbook, the estimated results is acceptable.

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