Review of large scale crop remote sensing monitoring based on MODIS data

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Abstract: China has a vast territory with abundant crops, and how to collect crop information in China timely, objectively and accurately, is of great significance to the scientific guidance of agricultural development. In this paper, by selecting moderate-resolution imaging spectroradiometer (MODIS) data as the main information source, on the basis of spectral and biological characteristics mechanism of the crop, and using the freely available advantage of hyperspectral temporal MODIS data, conduct large scale agricultural remote sensing monitoring research, develop applicable model and algorithm, which can achieve large scale remote sensing extraction and yield estimation of major crop type information, and improve the accuracy of crop quantitative remote sensing. Moreover, the present situation of global crop remote sensing monitoring based on MODIS data is analyzed. Meanwhile, the climate and environment grid agriculture information system using large-scale agricultural condition remote sensing monitoring has been attempted preliminary.

Key words: moderate-resolution imaging spectroradiometer (MODIS) data; remote sensing monitoring; crops

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0 Introduction

At present, the most convenient, economical and timely means in agricultural monitoring is remote sensing, which has unique advantages such as objectivity, fast speed, low cost, abundant information[1-2]. The rapid development of remote sensing technology makes the mankind enter the multi-level, multi angle, full range and all-weather observation time, especially in recent years the development of new high spatial resolution, high spectral and radar remote sensing technology, provides new opportunities for the modernization of agriculture management. Agriculture as one of the largest applications of remote sensing technology, extensive researches and applications have been carried out in crop yield estimation, investigation and dynamic monitoring of agricultural resources, agricultural disaster prediction and post-disaster assessment, vegetation surveys in our country. Using image information to conduct large-scale monitoring and crop yield estimation is an important aspect of the application in remote sensing technology.

In China, since the 1980s, crop yield estimation by remote sensing has made considerable progress. However, in the past twenty years, large scale crop information extraction is based on national oceanic and atmospheric administration/advanced very high resolution radiometer (NOAA/AVHRR) data[3-4], but it is subject to the limitations of its own data characteristics, and its monitoring accuracy needs to be further improved. Terra/moderate-resolution imaging spectroradiometer (MODIS)[5] is a new and important satellite remote sensor, the data performance has been greatly improved, and the launch of MODIS provides new opportunities for large scale crop monitoring and yield estimation.

This paper introduces the following contents:

1) Principle, content and development trend of crop remote sensing monitoring;

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2) Common data types, characteristics and different processing method of data types in remote sensing monitoring;

3) Processing method of MODIS data and selection and feature extraction method of characteristic band in crop monitoring;

4) The use of MODIS data for crop acreage monitoring and yield estimation;

5) The use of MODIS data for crop monitoring technology and methods in key regions;

6) Large scale agricultural climate environmental parameters grid technology.

1 Significance of crop remote sensing monitoring

Using remote sensing technology, agricultural remote sensing dynamic monitoring is based on spatial information technology for the agricultural production process. Agricultural remote sensing monitoring content is of major food crops planting area and crop layout, crop growth, agricultural disaster occurrence and development, crop yield growth process. The problem of food security is the major issues of national survival and development. Especially after the accession to the world trade organiation (WTO), agricultural remote sensing for security and grain trade in China to provide timely and accurate crop growth, area, quantitative disaster dynamic information, has become an important information source for decision making. Combined with conventional survey methods, a modern three-dimensional agriculture information collection processing and analysis system has been made. With the development of remote sensingspace technology, agricultural remote sensing monitoring of technology development and application are involved in a new period, and become an important part of the information agriculture, precision agriculture and digital agriculture.

In recent years, compared to the era of the planned economy, China's agricultural production is taking place profound changes, such as agricultural production is marketized gradually, in which market demand decides agricultural production. Therefore the interannual variability of crop planting area is larger, agricultural land utilize appears trend of pluralism and diversity, moreover, crop production has larger spatial and temporal difference due to the conditions of agricultural production and management measures, such as agricultural production environment of temperature, precipitation, soil moisture and so on. On the other hand, modernization of agricultural production management needs to grasp the agricultural information quickly and accurately and formulate a scientific and rational management measures of agricultural production and agricultural policy, which has strong business needs in decision-making. China has joined the WTO, scientific and accurate agricultural information has aided agricultural production management and decision is not only related to the healthy sustainable development of China's agricultural production and farmers' income increase, but also related to China's food security and social sustainable development. Obviously, large scale crop remote sensing monitoring is of great significance.

2 MODIS data features and roles

MODIS is one of the main sensors on the Terra and Aqua satellites equipped with two satellites in each, which may observe the entire surface of the earth to give 36 observations bands every 1—2 days. Multi-band, high-temporal MODIS data play an important role in global observations for natural disaster and ecological environment monitoring.

2.1 MODIS data features

MODIS data has four main features:

1) Toll-free. National Aeronautics and Space Administration (NASA) implement policies of global free-on MODIS data, such as data reception and usage is rare, inexpensive and practical for most scientists in our country.

2) Wide spectral range. MODIS data has a wide wavelength range (spectral range of 0.4—14.4 μm), higher data resolution than NOAA-AVHRR (up to 12 bits radiometric resolution, and the spatial resolution of 2 channels rate of 250 m, 5 channels of 500 m, 29 channels of 1 000 m). These data are comprehensive study of earth science, and researches on the land, atmosphere and oceans have different categories of high practical value.

3) Simple data reception. MODIS reception uses X-band to transmit to the ground, and adds a number of error-correcting capabilities in the data transmission to ensure users with a smaller antenna (3 m only) can get high-quality signal.

4) High updatingfrequency. Terra and Aqur satellites are sun-synchronous polar orbit satellites, and Terra transits morning information, Aqur transits afternoon information. MODIS data can obtain a minimum of twice a day and night. Terra and Aqur MODIS data in time on the update frequency matching, plus evening transit data, to the receiving frequency data updates, real-time earth observation and emergency treatment (such as forest and grassland fire monitoring and disaster relief) have a greater practicality.

2.2 MODIS roles

Analysis and researches of MODIS observation data play an important role in following aspects:

1) Land cover change and global productivity researches, including regional trends and changing patterns of land cover, biodiversity and global primary productivity.

2) Seasonal to interannual climate predictions, raising transient abnormal changes of climate prediction accuracy in time and space.

3) Natural disasters, including fires, volcanoes, floods and droughts and others; and long-term trends in climate change and its mechanisms, factors and impacts of human activities.

4) Monitoring changes, causes and impacts of atmospheric ozone.

3 Selection and time selection of MODIS bands incrop monitoring

3.1 Crop planting area monitoring and crop type information extraction

The monitoring of the large scale main crop planting area is the basis of crop yield estimation. Application of remote sensing technology can monitor changes of the nation's major planting areatimely and reliably. But the difficulty of crop area remote sensing monitoring is the crop type information extraction; the key is how to distinguish crops and other objects and different crops. Moreover, the identification of the crop is mainly based on the unique band reflectance characteristics of the green plants, so the crops are separated from the other objects. Therefore, the remote sensing monitoring of crop planting area is based on the spectral characteristics analysis of of different crops, and by using the remote sensing image recordings, the earth's surface information, the type of crop identification and crop area are analysed. To develop large scale crop area remote sensing estimation, we must solve three problems: accuracy, speed and efficiency, cost.

3.2 Calculation of MODIS characteristic band and characteristic parameters

MODIS band is relatively narrow, reducing the impact of water vapor absorption on the relevant bands, such as near infrared (NIR) bands, while the infrared band of chlorophyll will be more sensitive, which will greatly improve the quality of vegetation index. Feature band selection is an important part of remote sensing image recognition and classification. There is no correct feature selection to ensure that it is impossible to carry out an effective and accurate classification. Feature selection is application-oriented goals, it should consider 3 factors: the number of channel information content; the correlation between each channel data; the study area to identify the spectral characteristics of features. Specifications of the EOS MODIS bands are shown in Table 1.

Table 1 Specifications of MODIS bands

Band	Spectral range (nm)	Wavelength range	Resolution (m)
1	620—670	Visible light (red)	250
2	841—876	NIR	250
3	459—479	Visible light (blue)	500
4	545—565	Visible light (green)	500
5	1 230—1 250	NIR	500
6	1 628—1 652	Short-wave infrared (SWIR)	500
7	2 105—2 155	SWIR	500

Normalized difference vegetation index (NDVI)[6] is a simple, effective and empirical measure of vegetation activity on the surface of the earth. It is the ratio of difference between reflectance value and NIR reflectance values of the red band and the sum of reflectance value and NIR reflectance values, as shown in Eq. (1). NIR is located in the NIR band of the remote sensing channel to get the reflectivity; R is located in the visible red band of the channel to get the reflectivity. NDVI value can be used to determine the status of plant growth: plant chlorophyll photosynthesis and absorption of red light. The better the plant uptake of red light, the more reflection of NIR light. So the NDVI value can reflect plant biomass, and the greater the plant growth the better.

$$NDVI = (NIR - R)/(NIR + R). \quad (1)$$

In order to improve recognition accuracy, use land surface water index (LSWI) constructed with the two bands of NIR and ESWIR, and enhanced index constructed with the three bands of Red, NIR and Blue, as remote sensing characteristic parameters.

LSWI[7] is related to vegetation moisture content and has been successfully applied to the monitoring of soil moisture in the ecological environment. The calculation equation is shown in Eq. (2). Two sensitive bands of MODIS image on water content are: NIR (NIR1: 841—876 nm, NIR2: 1 230—1 250 nm) and SWIR band (SWIR1: 1 628 — 1 652 nm, SWIR2: 2 105—2 155 nm), respectively. In this study, NIR1 and SWIR1 band compute land surface water index with $LSWI_{1628}$. LSWI has certain advantages in vegetation water content monitoring. This method only needs to measure the vegetation information and consider the influence factors such as canopy structure and observation angle.

$$LSWI_{1628} = (\rho_{NIR1} - \rho_{SWIR1})/(\rho_{NIR1} + \rho_{SWIR1}). \quad (2)$$

Enhanced vegetation index (EVI)[8] is one of the vegetation indices generated by the MODIS data, and it is an improved soil atmospheric correction vegetation index. It uses the background adjustment parameter L and the atmospheric correction parameter C_1, C_2 simultaneously to reduce the background and the atmospheric function. In Eq. (3), ρ is reflected by the atmospheric correction value (NIR, Red, Blue); L is to adjust the parameters of soil ($L=1$). The parameters C_1 and C_2 are 6.0 and 7.5 respectively, and the gain coefficient G is 2.5. MODIS-EVI is constructed to deal with the problems of soil, atmosphere and saturation. By weakening canopy background signal, the sensitivity of biomass group can be improved, and the atmosphere effects is reduced to improve vegetation monitoring. The research shows that EVI is better than NDVI in vegetation monitoring.

$$EVI = G\,(\rho_{NIR} - \rho_{Red})/(\rho_{NIR} + C_1\,\rho_{Red} - C_2\,\rho_{Blue} + L). \quad (3)$$

3.3 Selection of multi temporal MODIS data

In order to adapt to the rhythm of the changing climatic conditions, phenology refers to the plant will form the corresponding plant development with this rhythm[9-10]. The phenology observation data of our country is very abundant, and the difference of phenology among different crops is the common basis for selecting the best phase of crop identification. The status and population characteristics of crops are the main factors that affect the spectral characteristics of crops. According to the distribution of crop phenology, the spectral characteristics of remote sensing images in different periods and different spectral characteristics of crops waiting period are different, selecting the best phase image to distinguish the different crops. For example, in early December, winter wheat is at stooling stage, while other vegetations have fallen, and background objects have large seasonal differences. Therefore, satellite images show obvious features of the image.

Through observation of winter wheat, remote sensing predicts corn crop yield[11-12]. Therefore, in the study area, phenology and growth stage of winter wheat and maize is crucial for crop yield estimation[13].

1) Wheat

Winter wheat development period is divided into the period of emergence, stooling stage, over wintering stage, greenup, up period, jointing stage, booting stage, heading stage, flowering stage, and mature stage. Wheat is divided into three stages, namely, the early stage of birth, the middle stage and the late stage of growth. In the study area, the growth period of winter wheat is from early October to mid-

June in the following year, the whole growth period generally has 230—280 d.

2) Maize

The phenophase of maize seedling, seedling stage, toast stage, tasseling stage, mature period, growth period. In the research area of maize from June to early October, growth period is generally 100 — 130 d.

4 Crop area remote sensing monitoring method and its application

4.1 Crop area extraction based on MODIS

Theoretical basis of data extraction of crop planting area using remote sensing is that in remote sensing images, the same object types in the same conditions (texture, topography, light, vegetation cover, etc.), should have the same or similar spectral information and spatial information feature. The essence is the analysis and selection of characteristic parameters according to the spectral characteristics of various kinds of features, and then the classification of remote sensing images is based on certain rules (classification algorithm). Among them, the feature selection and classification algorithm of different types of features is the key point of crop planting area extraction.

In the study, the choice of different scale and multi temporal remote sensing data should be paid attention in the study area, according to local meteorological data and other auxiliary data. In the analysis of data and the characteristic band, combine with crop spectral characteristics and biological characteristics, and comprehensively utilize of crop bio-temperature-information, extract appropriate characteristic parameters and improve the accuracy of the classification accuracy and extraction of the crops.

4.2 Method and analysis of remote sensing classification[14]

Maximum likelihood classification (MLC) method[15] is also called Bayes discriminant classification, according to the Bayes theory in the classification of the smallest probability of error in remote sensing image classification method.

Self-organizing neural network (SONN) classification[16-17] is proposed according to the "side inhibition" of the brain nervous system. SONN is essentially a non-supervised classification method.

Support vector machine classification method (SVM)[18] is a new machine learning method based on statistical theory of Vapnik2 Ch2ervonenkis (VC) dimension and structural risk minimization (SRM) principle.

Decision tree classification (DTC) method[19] is a kind of hierarchical processing structure in remote sensing classification, which has simple, clear and intuitive features.

Four methods are selected T11, T15, T19 and other 3 phase of the 7 Band reflectivity and EVI value as input data. 4 kinds of classification results were compared and analyzed, and then the performance of various classifiers was evaluated comprehensively. The accuracy evaluation is carried out by using the method of generating random samples. The total accuracy and Kappa coefficient are the overall measure of the classification results, as shown in Table 2.

Table 2 Comparisons of accuracy for four methods

Taxonomy	MLC	SONN	SVM	DTC
Total accuracy (%)	79.155 3	70.735 0	86.332 4	92.259 1
Kappa	0.749 0	0.647 4	0.832 8	0.901 7

As Table 2 shown, compared with other classification algorithms, DTC method is the best.

4.3 Extraction of winter wheat planting area

Fuzzy adaptive resonance theory map (ARTMAP) neural networks[20] use in the form of similarity between the two types of dynamic feedback method to select a subset of computing and fuzzy search feature space between the search and learning adaptive, which effectively combines fuzzy logic and adaptive feedback principle and advantages. Fuzzy ARTMAP with self-organizing feedback, incremental learning, highly complex mapping characteristics, compared with that of bp neural network, closer to simulate human perception and memory system, therefore it is suitable for application in the mapping and classification of high dimensional space.

Data source: in north China, winter wheat is planted from September to October, revived in mid-March, early heading in mid-May, harvested in late June. Here select the main winter wheat growing areas in Shandong, Hebei, Henan, Shanxi, Beijing and Tianjin as the research object. Remote sensing data are mainly Terra/MODIS data and Landsat TM data; geographic information system (GIS) data including spatial base maps and comprehensive agricultural zoning maps; other ancillary data including national agricultural statistics and the ground monitoring data (basic meteorological data and crop bio-temperature calendar data in each monitoring site).

Data preprocessing: First, feature extraction of winter wheat was based on Phenology Calendar in early October 2004 (the seedling stage) and early December MODIS data (the stooling stage), and two-phase preprocess generation in North China 250 m resolution when the two phases of remote sensing data sets with 7-band surface albedo.

The study area is divided into six categories: winter wheat, orchard and woodland, water, bare soil, urban land and other land. Therefore, for the fuzzy ARTMAP classification algorithm, the classification of input parameters is 7 data, the corresponding output results have 6 categories. By normalized processing of 7 data, all the input data are in the range of 0—1. For the quality inspection training area selection, before the classification, the introduction of J-M distance is used to measure the statistical divisibility among classes. The value is in the range of 0—2, under normal circumstances, the value greater than 1.8 indicates that the better separation between categories.

In the image to select 250 samples, from the M-J distance between the 6 types of samples are shown in Table 3.

Table 3 Separation degree between different classes' samples

	Winter wheat	Orchard and woodland	Other	Bare land	Urban land
Orchard and woodland	1.982				
Other	1.999	1.997			
Bare land	1.998	1.841	1.999		
Urban land	1.999	1.997	1.998	1.986	
Water body	1.999	1.999	2.000	1.981	1.999

Winter wheat planting area extraction result is based on MODIS spectral analysis. The fuzzy ARTMAP method for extracting winter wheat: first of all, use fuzzy ARTMAP classification algorithm to classify images and image classification from the calibrated planting area of winter wheat. Then, zone system to calculate the winter wheat planting area in different provinces, as shown in Table 4.

Table 4 Estimation of winter wheat area in North China area in 2004

Province	Winter wheat planting area (hm^2)
Beijing	31 800.00
Hebei	1 397 862.50
Tianjin	35 018.75
Shandong	4 135 831.25
Henan	5 717 712.50
Shanxi	286 200.00

Accuracy analysis: using the same period in North China (November 27, 2004) as a scene Landsat TMl23/33 data to verify the result. The crop is relatively single in North China. When other vegetation mostly have overwintering leaves, winter wheat goes into the stooling stage, which is easy to get reflected in remote sensing images. In order to do effective comparison, firstly, use mask technology and intercept the same size in the same area MODIS extracted TM distribution of winter wheat. Secondly, using the spatial analysis function of GIS software, the pixel area of each MODIS pixel is extracted to be more than 50% pixels, which is the result of TM extraction from wheat. Finally, based on MODIS, extracted winter wheat distribution is resampled as 30 m×30 m to perform precision analysis. The trend of spatial distribution of winter wheat based on MODIS and TM extraction was basically consistent. In order to quantitative evaluation the accuracy and extract the TM of the winter wheat as a reference value, randomly select 512 samples (including 256 winter wheat and 256 other types), a confusion matrix calculated the producer's accuracy and user accuracy and total accuracy, as shown in Table 5. Despite its user accuracy and total accuracy reached 85.2% and 80.3%, producer's accuracy is only 77.6%, indicating that actually 22.4% of winter wheat was mistakenly classified for other classes, and in contrast, other misclassified is 16.5% for winter wheat. In other words, due to its low spatial resolution, using MODIS to identify wheat is easy to cause the winter wheat "omission" and the false division for other classes, especially in small plots and scattered region of the wheat. This has resulted in the calculated winter wheat area by MODIS was less than the actual size. By using fractal theory in large scale (low resolution), MODIS unit measured area is modified, so that it is closer to the actual area estimation.

Table 5 Evaluation of winter wheat identification accuracy

	Winter wheat	Other	Users accuracy (%)
Winter wheat	218.0	38.0	85.2
Other	63.0	193.0	75.4
Producer accuracy (%)	77.6	83.5	
Overall accuracy (%)		80.3	

4.4 Extraction of crop area in autumn

Decision tree method has the following advantages: fast speed, less calculation amount and easily convert into classification rules, mining classification rules with high accuracy, easy to understand, so the decision tree can be clearly showed which fields are more important.

Data sources: the remote sensing data is mainly Terra/MODIS data; GIS data mainly includes space foundation drawing such as administrative zoning map data and special spatial data such as land use and land cover data, comprehensive agricultural regionalization map; other auxiliary data is the main national agricultural statistics and the ground monitoring data (basic meteorological data and cropbio-temperature calendar datain the monitoring sites).

Data pretreatment: Beijing area in 2002, the main autumn crops are corn, soybeans, cotton, rice and peanuts. According to the requirements of the national agricultural remote sensing monitoring, 5 Chinese staple crops (winter wheat, corn, soybeans, cotton, and rice) conduct remote sensing monitoring. Therefore, only summer maize, maize, summer soybean, cotton and rice were monitored and analyzed. According to the study area, mainly autumn crop bio-temperature calendar features were extracted in late April in 2002 (sowing period of cotton and maize), in early June (transplanting period of rice), in late June (sowing period of summer soybean and maize), in late July (heading stage of cotton flowering rice), in early August (tasseling stage of spring maize), in mid-August (pumping heading stage of summer maize) and in late September (mature period of cotton and rice). A total of 7 MODIS data resolution for the reunification was 250 m.

Extracting results of autumn crop area based on decision tree method: according to corn, soybean, cotton and rice bio-temperature calendar features and spectral characteristics of different crops in various phases, use decision tree classification scheme to identify the kinds of crops. Firstly, the 7 Red bands, NIR bands, and ESWIR bands, and 4 Blue bands, and LSWI and EVI are extracted and generated. Secondly, according to the research area of the several main autumn crop bio-temperature characteristics and spectral features, it can be seen that, in late April, the cotton and maize are seeding with smaller EVI values, which can extract of cotton and spring corn initially; in late July, cotton is at flowering stage, the EVI reaches the maximum; in early August, spring corn is at heading stage with the maximum EVI, which can separate the spring corn and cotton. In addition, cotton is maturity in late September, while other crops have already harvested, so cotton can be further identified according to this characteristic. Thirdly, since rice is transplanted in early June, exhibiting some properties of water bodies, so LSWI is larger than the EVI. In late July, rice is at heading stage with maximum EVI value. In late September, rice is still maturing period, EVI has a certain value, thus rice can be identified. Finally, due to its growth period of summer corn and soybeans were similar, only bio-temperature characteristics were difficult to distinguish. But they are sown in late June, usually after the wheat harvest, and therefore have a lower EVI value, while other crops such as cotton, corn and so spring have entered the jointing stage with higher EVI, which can initially identify summer corn and soybeans. According to differences in spectral characteristics of soybean and summer corn (greenness value of summer corn is greater than soybeans), summer corn reached the peak value in mid-August and soybeans is in the early August, which can further distinguish them. However, according to the relevant data, autumn crops, peanuts account for a portion of the extracted other autumn crops have some interference in Beijing, which must be considered. In research area, biological flower phenology calendar features show that peanut is generally planted in mid-May. In late June, its EVI has a certain value, while summer corn and summer soybean are just planted at this time with lower EVI value. Thus, it can be removed for effect of peanut on summer soybean and summer corn. By late July, nearly two months after planting peanuts, there is more intense photosynthesis, and it has a high EVI value and greater than the value of EVI in late June, but it still less than 0.60 and greater than 0.60 at a time of spring maize, accordingly also eliminate its impact on cotton spring corn extraction.

Accuracy analysis: in order to verify the accuracy of the extracted from the result, compared with statistical results of the national agricultural statistics bureau in 2002, the monitoring precision was 86%, including corn of 90.7%, soybean of 87.3%, rice of 86.5%, and cotton of 92.3%, as shown in Table 6. According to the different crop phenology calendar features, multi-temporal MODIS images using the decision tree method can accurately extract the autumn crop type information and accuracy can meet the requirements of large scale agricultural remote sensing monitoring.

Table 6 Comparison of monitoring accuracy with statistics results of planted area

Autumn crop type	Corn	Soybeans	Rice	Cotton
Remote sensing area (hm^2)	79 118.75	17 518.25	3 868.75	2 868.75
Agricultural statistics area (hm^2)	87 239.2	15 542.5	4 472.5	3 107.5
Relative error (%)	−9.3	12.7	−13.7	−7.7

4.5 Error source analysis

In remote sensing applications, the error is mainly caused by the data source itself and generated during the data processing. Errors present in the data, the data quality problem is also an objective existence. Remote sensing data sources and non-remote sensing data sources are the basis of the whole crop type information extraction and the main error sources.

Remote sensing MODIS data inclueds MODIS radiance distortion; geometric distortion of MODIS data; spatial resolution limit (three problems can be improved through the image processing technology, such as radiometric correction, geometric correction, mixed pixel decomposition, etc.)

Non-remote sensing auxiliary data: in the study area, remote sensing image interpretation itself with an unforeseen error, and with the development of urban and rural areas, most of the arable land in China has also changed. The vector data of the administrative boundaries are surveyed by the State Department of surveying and mapping, which is based on the TM meteorological data, statistical data, land use data, administrative division data.

The error of the data processing process influence the effect of registration and crop type extraction model.

Conclusion: crop remote sensing recognition is an important part of agricultural remote sensing monitoring. It is the basis of crop acreage extraction and yield estimation, and it has a special significance. By using MODIS/Tewa data, the spectral analysis method is used to select the appropriate band, using multi-temporal features to establish a wide range of remote sensing image recognition method—fuzzy ARTMAP. Practice shows that only using MODIS's own spectral information is to realize the full coverage automatic recognition of crop type remote sensing. However, due to the limited spatial resolution of MODIS, it is still unable to identify the small plots and sporadic distribution of crops, with the area of the crop is often less than the actual area. In order to further improve its accuracy, one of the effective methods is to use mixed pixel decomposition technique, or establish the sampling methods and technique system according to the running of the business by using high resolution remote sensing data and sampling theory. In large scale, in order to reduce costs and improve the monitoring accuracy, establish relationship between the MODIS data and less high resolution remote sensing data, which can amend MODIS measured area to make estimate results closer to the actual value.

5 Crop yield remote sensing estimation and current situation

Crops yield estimation has become a problem in the long period of stability in the country. Estimation methods includes traditional statistical methods and various models methods. Although crop growth mechanism model and crop yield prediction model depend on ground truth data calibration in rationality, independence and development potential has a strong advantage, in terms of maneuverability, the statistical model based on remote sensing has certain application value in the crop yield estimation in the current and future period. Further research of yield estimation model with various remote sensing indexes should be strengthened.

5.1 Remote sensing estimation of crop yield

In remote sensing estimation of crop yield[21-24], crop yield components include meteorological factor, anti-anti-factor and random factors. In crop yield estimation model, the model of crop yield prediction at home and abroad is very popular; generally speaking, it can be divided into agricultural model, meteorological model, remote sensing model, statistical model and crop growth simulation model.

From the view of large scale point, the crop yield model needs to meet the following requirements: universality; availability; speed. According to the number and types of parameters used in model, it can be summarized into the following three types: remote sensing parameters yield model (vegetation index model of yield, photosynthetic active radiation yield model, temperature model of yield, water yield model); multi parameters remote sensing yield model (green degree temperature yield model, vegetation index of water yield model, green photosynthetic effective radiation yield model, radiation model of water yield); remote sensing parameters and meteorological factors yield model.

Use statistical data of study area of wheat and maize yield to calculate per unit area yield. Based on meteorological and remote sensing parameters, establish remote sensing model, meteorological yield model and remote sensing meteorological yield model of wheat and maize. Do regression analysis by selecting optimal estimation phase data, the annual data and yield respectively. Finally, a high precision model is obtained.

1) Wheat remote sensing meteorological yield model

On the basis of previous data, by comparison of meteorological yield model and remote sensing yield model, it can seen that remote sensing yield model is better than meteorological yield model. Combing meteorological factors affecting the production and remote sensing parameters, establish a linear relationship between the models and the yield to predict wheat yield.

2) Maize remote sensing meteorological yield model

On the basis of previous data, by comparison of meteorological yield model and remote sensing yield model, it can seen that meteorological yield model is better than remote sensing yield model. Combing meteorological factors affecting the production and remote sensing parameters, establish a linear relationship between the models and the yield to predict maize yield.

5.2 Status of global crop remote sensing monitoring

Remote sensing has always been the focus of governments, and the development of this already achieved great success. Internationally, besides crop monitoring system set up by many countries in the world to serve theri own country, the United States, the European Union and the World Organization

(FAO) also set up their own regional or global crop monitoring system to monitor and risk assess for grain yield of global or focal areas, which provides timely and reliable global or regional agricultural production information for the respective countries and institutions[25]. With the rapid development of remote sensing technology at home and abroad, more and more global coverage of high temporal and spatial resolution in remote sensing information sources can be used to extract high-resolution crop distribution information, so that crop yield estimation and application become possible based on mid-high or high resolution crops distribution information, such as Landsat series information sources.

In our country, after many years of technology accumulation, and based on a lot of researches, Chinese Academy of Sciences, National Meteorological Bureau and Department of Agriculture have carried out crop yield monitoring of wheat, corn, soybean and rice in foreign grain producing areas, and achieved a series of monitoring results, which provides reliable reference information for the national and sectoral decision-making. Chinese Academy of Sciences firstly released global major grain producing areas and wheat, corn, soybean and rice production in main grain-producing countries in 2013, and analyzed factors of production and environment in major grain producing areas and the main producing countries. With the gradual establishment and improvement of high-resolution earth observation system, remote sensing data acquisition capabilities to produce high-resolution surface information will be further enhanced. In the future, use of high-resolution remote sensing data acquisition and distribution of high-precision crop growing information to carry out domestic even large-scale worldwide crop yield estimation has been made possible and inevitable trend.

Global crop yield estimation work is a long-term and complex technical work, which not only requires the timely and accurate estimation results, but also needs strong operability of estimation method. Therefore, further research of the relationship between crop growth and yield is needed to select the best estimation data and establish the yield estimation model, which can compress processing time of remote sensing data and improve the efficiency of the system.

6 Information Grid Technology of agricultural climate environment

Agricultural climate environment information is an important part of agricultural information. However, it is difficult to meet the requirements of high spatial and temporal resolution grid data for the ground meteorological data at the present stage. Therefore, based on GIS and remote sensing technology, combined with the ground observation data to study agricultural environmental information grid method, and then the establishment of agricultural climate environmental information grid has become the focus of research in recent years[26].

The grid information system of agricultural climate environment refers to divided the land resources into several grids with the latitude and longitude, and establish the agricultural climate environment information system in thess areas. Due to the advantages small regional unit, clear boundary, specific geographic information and high precision of climate factors, it has a wide range of applications and has become extremely important basic information of environmental assessment on agricultural and resource exploitation. Studies in these aspects have made in abroad, such as grid map of the climate has become the replacement of the conventional agriculture climate diagram (contour).

In recent years, a lot of researchers are doing this work in our country, but the main emphasis are on theoretical aspects with less elements involved. Climatology calculation model is mainly based on ground station observation data according to the empirical formula, which often ignore the influence of complex terrain factors and is difficult to achieve the practical level.

7 Conclusion

1) Due to strong macroscopic remote sensing and data acquisition periodization characteristics, crop growth and yield can be monitored amd forecasted effectively. At the same time, agricultural production

is a very complex system, factors of reflecting crop growth are not only the meteorological factors and remote sensing information mentioned above, fertilizers, pest and others should be considered. So, there is a gap between model and production. The future researches should be done to improve the model and improve the practicability.

2) The relevant statistical model and rational regression method selection are closely related to the data representativeness. so the model is ineffective in directly application. MODIS time-series data contain a lot of vegetation information. It is needed to explore useful information in depth for crop growth.

3) Planting situation in our country is complex, there is less large-scale cultivation of single crops. It is difficult to achieve the desired accuracy by the use of MODIS data in estimation of crop area, growing and production. It requires a combination of other means, such as digital elevation models, to do comprehensive analysis.

4) Since the low resolution of MODIS images, mixed phenomena in complex terrain, farming system diverse areas may occur, which leads to low forecasting and monitoring accuracy. In order to develop the potential applications of MODIS in crop yield estimation, combination of spectra, quantitative parameters inversion, crop growth model, data mining and mixed pixel decomposition need to be further studied.

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基于 MODIS 数据的大尺度作物遥感监测综述

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摘　要： 我国幅员辽阔，作物种类丰富，如何及时、客观、准确地收集我国作物信息，对科学指导农业发展具有重要的意义。本文以 MODIS 数据为主要信息源，以农作物的波谱特性和生物学特性机理为基础，开展利用 MODIS 数据的高光谱多时相及免费获取的优势，进行大尺度农情遥感监测研究，发展了适用的模型和算法，实现大尺度主要作物类型信息的遥感提取和产量遥感估算，提高了农作物遥感定量精度，并探讨了基于 MODIS 数据的全球农作物遥感监测的现状。同时，针对大尺度农情遥感监测中涉及的农业气候环境网格信息系统做了初步尝试。

关键词： MODIS 数据；遥感监测；作物

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