RESEARCH ON REMOTE SENSING MEASUREMENT OF THE CROPS PLANTING SPATIAL DISTRIBUTION IN TAIHE COUNTY OF ANHUI PROVINCE

Feng Guan[1], Shengyong Guan[1], Baiyang Ren[1], Hong Yu[1], Huizhen Zhou[1], Longlong Li[1]
[1]Twenty First Century Aerospace Technology Co., Ltd., Beijing 100096, China
Email:guanfeng@21at.com.cn

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ABSTRACT: We carried out the planting spatial distribution of the main autumn harvest crops through remote sensing measurement in Taihe, including corn，soybean，sweet potatoes. For that purpose, we used GF1(16m) images to implement crop information extraction and result production, combining crops related planting rule and phonological information, and take the relevant provisions of the third national agricultural census as the guiding principle. This work involves a series of technology processes, including phenological information research, data preparation and preprocessing, interpretation knowledge base establishment, measurement area division, training sample extraction, crop spatial distribution extraction, etc. At last, we evaluate the measurement results, and get the total area precision, the producer precision and the user precision of three kinds of crops, the results were all above 95%.The results indicate that, this set of crops distribution remote sensing measurement process has good practicality, normative and high accuracy. So it can provide a practical and effective technical process and implementation plan for the remote sensing measurement of crop spatial distribution in the third national agricultural census, as well as provide a scientific basis for the structural adjustment of major crops in the region.

1. INTRODUCTION

Crop planting structure including the information of crop species and spatial distribution, we need to grasp the situation of crop planting structure in time, and adjust the planting strategy according to the scientific theory and technology. It not only affects the economic benefits of local farmers, but also relates to the comprehensive and rational utilization of agricultural resources in the local areas (Zhang et al., 2008). Remote sensing technology can obtain the spatial distribution information of crops rapidly and intuitively in the survey area, so it has been applied to land use and land cover survey in recent years. The method overcomes the disadvantages of the traditional agricultural statistics like progressive reporting and field measurement methods, meanwhile, it improves the statistical accuracy, reduces the statistical error, saves great deal of manpower and material resources. In order to meet the great demand of new situation of agricultural statistics, and improve the quality of the survey data on major agricultural products of grain, cotton and oil, the National Bureau of statistics has gradually to promote the remote sensing measurement of crop area in the country since 2010. Remote sensing measurements of the major crops spatial distribution have been carried out currently in many provinces throughout the country.

The essence of the crop planting spatial distribution measurement is remote sensing classification. Through the difference of spectral characteristics and textural features of different crops in remote sensing images, the purpose is to distinguish crop categories, monitor crop spatial distribution patterns and planting area (Yang et al., 2004). In accordance with the 2016 work schedule of the National Bureau of statistics, the third agricultural census were carried out nationwide, aiming at the crop planting spatial distribution remote sensing measurement in different provinces. This paper is based on the widely used medium and high resolution remote sensing satellite data, and taking Taihe County as the example area. Combining the planting rules of crop and phenology in the study area, we carry out planting space distribution measurement of corn, soybean, sweet potato and other main harvest crop in

Taihe County, through a series of study of the technological processes and methods. The purpose is to provide data support and technical support for the daily statistical work of various statistical departments, and to form standardized, and large-scale remote sensing measurement technological processes and working methods.

2. DATA AND METHODS

2.1 Research Area

Taihe County is located in the northwest of Anhui Province, where is in the southern part of Huang Huai plain, between the two cities of Fuyang and Bozhou. It is located at East longitude 115°25′~115°55′, North latitude33°04′~33°35′, the total area is 1822 square kilometers, and the cultivated land area is 1.72 mu, with a population of 1.712 million. Taihe County is located in the eastern part of Asian continent, the climate is warm temperate semi humid areas in Eastern monsoon, and close to the northern subtropical climate, which is characterized by obvious four seasons, monsoon climate, adequate light, mild climate, abundant rainfall.

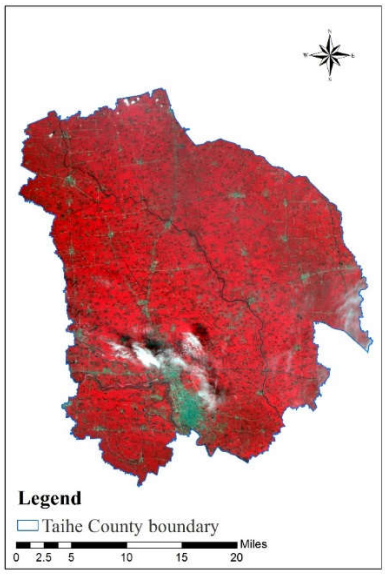

Figure 2-1 Remote Sensing Image of Taihe County in Anhui Province

2.2 Data preparation

Data is the basis of remote sensing measurements. The required data including image data and auxiliary statistical data, image data mainly refers to satellite remote sensing data, auxiliary statistical data mainly include crop sample data, agricultural statistics data, crop phenology data and so on.

2.2.1 Image data screening and pretreatment

The image data need to be screened and pretreatment before information extraction, according to the "Detailed rules for the production of remote sensing image data for the third national agricultural census ", we mainly investigate the image resolution, spectral band, image type, image phase and image quality and coordinate system, also unified projection and coordinate system according to the specification.

The remote sensing image data is based on GF1-16m resolution multi spectral data, and 8m image data appropriate to supplement. The image contains 4 bands, blue, green, red and near infrared. The image information needs to be able to accurately reflect the contents and the boundaries of the main objects as vegetation, soil, water, buildings.

We need use HJ-1/Landsa8 data instead of GF1 data in some areas. The data will be from October 2015 to early October 2016, what is from three phases at least of the key period from the date of planting to the period after harvest. The image coordinate system adopts the national geodetic coordinate system CGCS 2000, the elevation datum is 1985 National elevation datum, and the projection adopts Albers projection. The image is characterized by the view that the amount of cloud and snow is not more than 10%, the quality of the map surface is rich, the texture is clear, the hue is even, the contrast is moderate, and there is no obvious noise, bad spots or bad lines. The image is taken as a unit of view, the amount of cloud and snow in the image is no more than 10%. The quality requirements of the image surface are rich in layers, clear in texture, balance in color and moderate in contrast, and no obvious noise, bad spots or bad lines.

The image data preprocessing includes image orthorectification, image registration, fusion, mosaic, uniform color, image cutting and finishing drawing, and each link has the strict quality inspection and precision control process. The purpose is to ensure that the product can reach the image measurement accuracy requirements of agricultural statistics.

Table 2-1 Image Data Content

Data type	Data source	Data name	Acquisition time
Mid spatial resolution remote sensing image	GF1	GF1_WFV3_E115.3_N33.9_20150619_L1A0000871618	2015/06/19
	GF1	GF1_WFV1_E116.4_N33.0_20150827_L1A0001002810	2015/08/27
	GF1	GF1_WFV3_E115.6_N33.9_20151012_L1A0001095403	2015/10/12

Based on the phenology information and the planting laws of the main crops such as corn, soybean and sweet potato in Taihe County, we selected three GF1-16m resolution image as the basis for measurement of image classification ultimately, considering the growth cycle of other disturbed crop. Image details as shown in Table 2-1.

2.2.2 Sample database collection

The sample database is provided by the provincial investigation team of the National Statistics Bureau, the investigation teams at the municipal and county levels are responsible for the collection of data and the delivery of the results, and building the sample database in accordance with the requirements of the National Statistics Bureau. Sample data plays an important role in the whole process of image interpretation. It is mainly used for crop discrimination, crop analysis and precision test.

2.2.3 Agricultural statistical database preparation

Agricultural statistics are based on county-level units and link historical (2014-2015) agricultural statistics to county-level administrative units. Agricultural statistics are mainly provided by the Bureau of statistics, at the same time，the network and field research are carried out according to the actual needs of the project,. Agricultural statistics are mainly used to assist in precision checking and identification of crop species.

2.2.4 Phenology database preparation

A database of phenological characteristics of each county's main crop is developed, which describes the entire

growth cycle of the crop. The construction of phenology database mainly depends on the phenological data of National County in 2010 and the latest phenological data collected according to the requirements of the project, which build the database in accordance with the National Bureau of Statistics

2.3 Methods

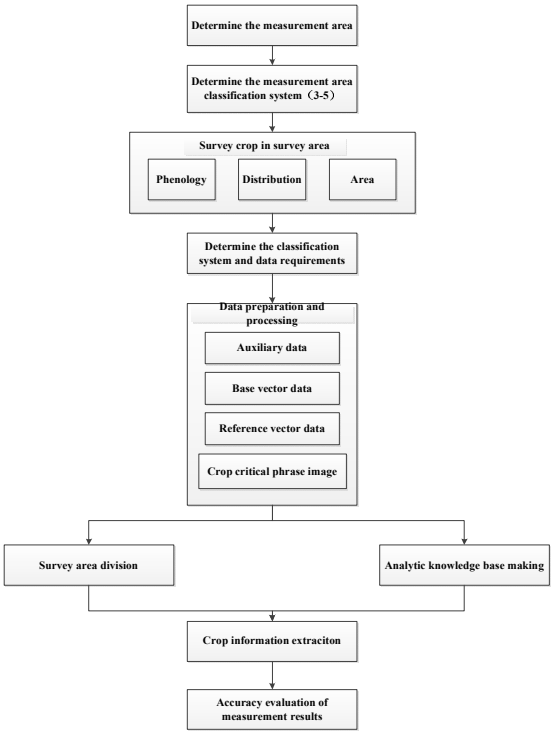

Figure 2-2 Taihe County Remote Sensing Measurement of Spatial Distribution of Crop Planting Flow Chart

The process of measuring the spatial distribution of crop planting in Taihe County is mainly aimed at the crops widely distributed in the county. Based on the full study of phenology information and crop growth law in the early stage, the spatial distribution of crop growing areas was measured through a series of technical processes such as survey of crop crops in the survey area, determining the measurement zone classification system and data requirements, Image data and auxiliary data preparation, Interpretation knowledge base production, measurement area division, crop information extraction and precision evaluation. The technical roadmap is shown in figure 2-2.

2.3.1 Interpretation knowledge construction

2.3.1.1 Phenological phase analysis

Phenological analysis is one of the basic conditions to establish the interpretation of knowledge base, but also provide a theoretical basis for the selection of critical period images in crop information extraction, this study is mainly based on the phenology of the different growth period of crops of major crops. In this study, the phenology of major crops was analyzed according to the growth period of different crops.

（1） Phenology analysis of corn

Corn in Anhui province are mainly distributed in the north of the Huaihe area, planting types include spring corn and summer corn, through the collection and analysis of meteorological data, agricultural data and statistics, fully understand the different types of cornat different growth stages of the time distribution, as shown in Table 2-2. The

growth stages of corn include sowing time, emergence stage, jointing stage, male stage, flowering stage, silking stage and mature stage. Taihe County planted corn mainly summer corn.

Table 2-2 Phenology of Corn of Different Sowing Types in Anhui Province

Seeding type	March	April			May			June			July			August			September			October	
	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m
Spring corn	Sowing stage	Seeding stage			Jointing stage		Tasseling stage	Flowering stage		Silking stage	Mature stage										
Summer corn								Sowing stage			Seeding stage		Jointing stage	Tasseling stage		Flowering stage	Silking stage		Mature stage		

（2） Phenology analysis of soybean

Anhui province soybean planting types including spring and summer soybean, through the collection and analysis of meteorological data, agricultural data and statistics, fully understand the different types of soybean during each growth period of time distribution, as shown in Table 2-3. Soybean growth stage including germination period and seedling period, flower bud differentiation, flowering, pod filling stage and mature stage. The soybean grown in Taihe County is mainly summer soybean.

Table 2-3 Phenology of Soybean of Different Sowing Types in Anhui Province

Seeding type	May	June			July			August			September			October
	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f
Spring soybean	Germination stage		Seeding stage		Flower bud differentiation stage		Flowering stage	Pod setting and seed filling stage		Mature stage				
Summer soybean		Germination stage		Seeding stage	Flower bud differentiation stage			Flowering stage	Pod setting and seed filling stage			Mature stage		

（3） Phenology analysis of sweet potato

Anhui province sweet potato planting types include spring and summer sowing sweet potato sweet potato, through the collection and analysis of meteorological data, agricultural data and statistics, fully understand the different types of sweet potato planting each growing period of time distribution, as shown in Table 2-4.The growth period of sweet potato mainly includes sowing, emergence stage, rooting stage, seedling stage, branch and tuber stage, stem and leaf growth period, stem and leaf decline, tuber enlargement stage and mature harvest period. Taihe County planting sweet potato, mainly summer sweet potato.

Table 2-4 Phenology of SweetPotato of Different Sowing Types in Anhui Province

Seeding type	4 月			5 月			6 月			7 月			8 月			9 月			10 月		
	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l	M_f	M_m	M_l
Spring soybean		Sowing and seeding stage		Rooting and recovery seeding stage			Branch and tuber stage						Stem and leaf growth stage			Stage of stem and leaf declined and tuber mass increased			Ripe harvest stage		
Summer soybean							Sowing and seeding stage			Rooting and recovery seeding stage			Branch and tuber stage			Stem and leaf growth stage			Stage of stem and leaf declined and tuber mass increased			Ripe harvest stage		

2.3.1.2 Analytic knowledge base construciton

In the process of constructing the knowledge base of interpretation, we should analyze and sum up the detailed interpretation knowledge specification in accordance with the principles of scientific, normative and practical. Phenology data were obtained by county as a unit, the typical spectral characteristics of the sowing period, growth period and harvest period of corn, soybean and sweet potato in Taihe County of Anhui province were obtained, and the planting characteristics and scale of main planting areas were collected. In order to form a complete set of typical spectral interpretation knowledge base of corn, soybean and sweet potato, we need the county corn, soybean, sweet potato information extraction standards, image features, reference standards, interpretation, knowledge base, data entry rules and other standards.

Table 2-5 Description Documents of Main Crop Interpretation Knowledge Base of Taihe County in 2015

ID	Key_ID	DWLX	RSMC	RSHQSJ	JLST	YP
1	1-1	Summer corn	341222_GF1_1315218_20150827_DOM	2015/8/27	2016/5	
2	1-2	Summer corn	341222_GF1_1315218_20150827_DOM	2015/8/27	2016/5	
3	1-3	Soybean	341222_GF1_1315218_20150827_DOM	2015/8//27	2016/5	
4	1-4	Soybean	341222_GF1_1315218_20150827_DOM	2015/8/27	2016/5	
5	1-5	Sweet potato	341222_GF1_1675875_20151012_DOM	2015/10/12	2016/5	
6	1-6	Sweet potato	341222_GF1_1675875_20151012_DOM	2015/10/12	2016/5	

2.3.2 Survey area division

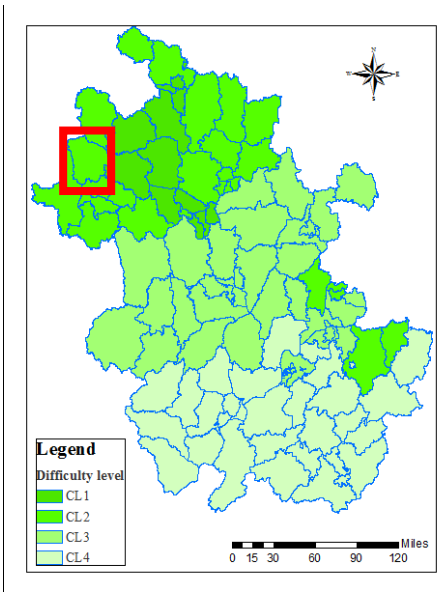

Figure 2-3 Difficulty Grade Map of Autumn Harvest Crops in Anhui Province

The division of surveying area refers to the division of the degree of difficulty of the survey area. Based on the principle of measuring area division, the difficulty and degree of crop identification are interpretation, according to the definition of the difficulty grade of the measuring area. The classification of the difficult level of the measurement area is based on the principle of measuring area division and the determination of the difficult level of the measuring area in "Detailed rules for remote sensing measurement of planting spatial distribution of major crop in the third national agricultural census", and survey the types and area of crops in the survey area, and the proportion of the plain and mountainous areas, taking into account the difficult level classification map of Anhui Province, the map shows that Taihe County belongs to the 1 types of areas, and the remote sensing measurement is less difficult.

2.3.3 Crop information extraction

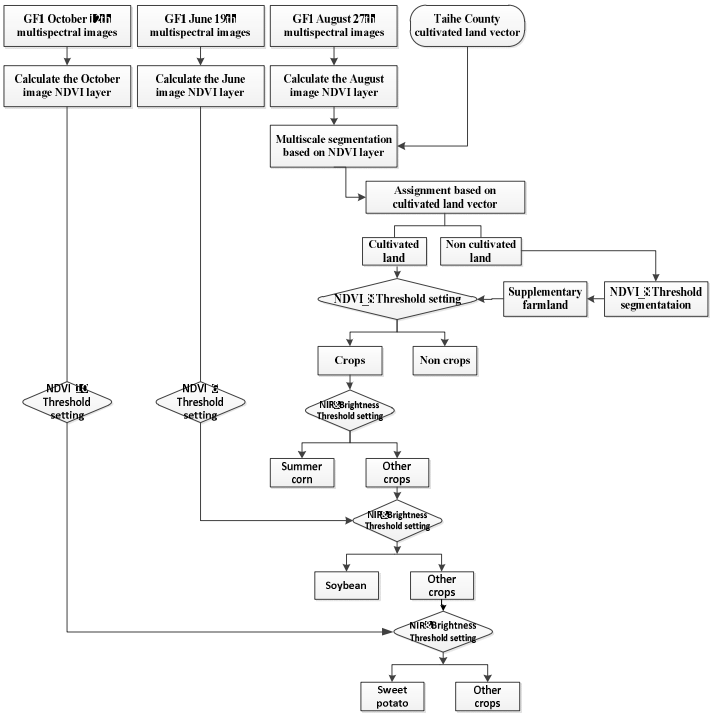

Figure 2-4 Flow Chart of Main Crop Information Extraction in Taihe County

In accordance with the relevant technical requirements of the third agricultural census crop classification training samples and measurement extraction rules, Taihe County in Anhui province were selected as the sample area, according to the survey analysis, the sample area of autumn crops mainly for corn, soybean and sweet potato crop distribution characteristics which show soybean and corn basically is a large centralized distribution, sweet potato is a small area with broken distribution(Yan et al., 2005). Thephenological characteristics of crops showed that summer maize and summer soybean were sown mainly in middle and late of May, emergence at the end of June, and filling in early September, harvest at the end of September to the beginning of the October, sweet potato is divided into spring and summer sweet potato, sweet potato, spring sweet potatoes are sown in middle and late of April, summer sweet potatoes are sown in middle and late of June, they are ripe for harvest at the end of October; From the features of crop performance, the three main crops are in vigorous growth period at the end of August, true color image of corn vigorous growth stage was dark green, in the true color image, the corn grows vigorously, displays the blackish green, soybeans, sweet potatoes and cotton are all green, in the middle of October, corn and soybeans were exposed in the nude, and sweet potatoes were green, in June, cotton was green and other crops were exposed. Therefore, taking into account the August to distinguish the corn and soybean / cotton / sweet potato mixture, in June, cotton and soybeans were identified, and soybeans and sweet potatoes were separated in the

middle of October, therefore, we select the June, August and October images for soybean information extraction. Taking into account the fragmentation of crops, we choose the method of extracting information based on pixels and objects(Li et al.,2011;Jia et al.,2014), and the technical flow chart is shown above.

According to the above process, the main crop information extraction results of Taihe County were obtained by comprehensive analysis, as shown in the following figure.

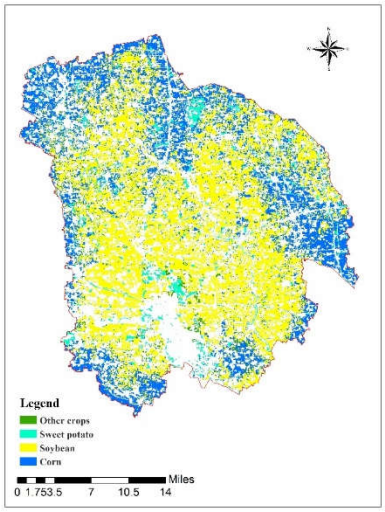

Figure 2-5 Results Map of Spatial Distribution Measurements of Main Crops in Taihe County

3. ACCURACY EVALUATION

Taking county as the unit, the error matrix is used to evaluate the accuracy. The first is the selection of test points, test point selection based on hierarchical partitioning for each crop spatial distribution map, and randomly sampled 100 test points, then we combine the translation knowledge base and prior knowledge, calibration of object types at random test points, and take this as the reference data(Hao et al.,2011). Finally, the error matrix of reference data and each crop classification result is calculated, and the precision evaluation result is obtained according to the formula of the total precision, the producer accuracy and the user accuracy. The calculation formula of accuracy evaluation is as follows.

$$\text{Overall accuracy：} \quad \mathrm{OA} = \sum x_{ii} / N$$

$$\text{Producer accuracy：} \quad \mathrm{PA} = x_{ii} / x_{+j}$$

$$\text{User accuracy：} \quad \mathrm{UA} = x_{ii} / x_{i+}$$

X_{ii} stands for the number of categorical data on the diagonal, consistent with the reference data, N stands for the total number of checkpoints, X_{+j} representing the total number of checkpoints in column J, X_{i+} representing the total number of checkpoints in line I.

The confusion matrix is used to evaluate the precision of information extraction in Taihe County, including the selection and calculation of test point error matrix.

3.1 Test point selection

The first is based on selected test crop spatial distribution data, 100 test points were selected according to each type of stratified randomly. Secondly, we use the prior knowledge of Interpretation knowledge base to demarcate object types at random inspection points, and use it as reference data. Finally, the error matrix is established according to the reference data and the classification results, the overall accuracy of crops and non-crops, the producer accuracy and user accuracy of single crops are calculated. The spatial distribution map of the 500 test points is shown in

Figure 3-1. 000 stands for other objects, 102 represents corn, 115 represents soybean, 119 represents sweet potato, and 146 represents other crops.

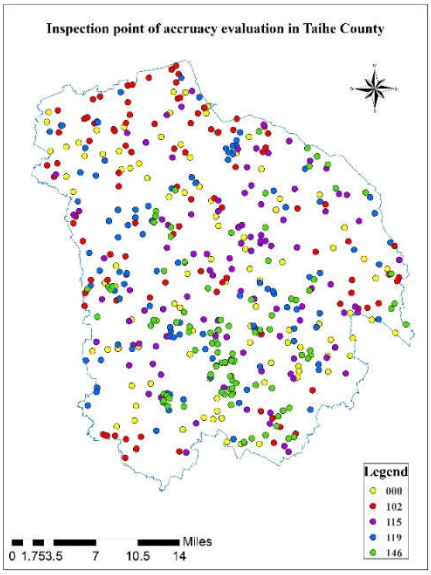

Figure 3-1 Test Points Distribution Map of Taihe County

3.2 Error matrix estimation

The error matrix is mainly based on the error matrix established by the reference data and the classification result data, what is used to measure the overall accuracy of crops and non-crops. Similarly, the accuracy and user accuracy of single crop producers are also measured. The error matrix is shown in Table 3-1.

Table 3-1 The Error Matrix of Crops Information Extraction Result in Taihe County

Reference data / Categorical data	Corn	Soybean	Sweet potato	Other crops	Others	Total
Corn	95	1	0	0	1	97
Soybean	2	96	1	2	0	101
Sweet potato	2	0	97	0	2	101
Other crops	1	1	1	98	0	101
Others	0	2	1	0	97	100
Total	100	100	100	100	100	500

（1）Overall accuracy：OA = (494/500)*100% =98.8%（Crops and Non Crops）

（2）Precision of single crop：

1）Corn

Producer accuracy：PA = (95/100) *100% = 95%

User accuracy：UA = (95/97) *100% = 97.94%

2）Soybean

Producer accuracy：PA = (96/100) *100% = 96%

User accuracy：UA = (96/101) *100% = 95.05%

3）Sweet potato

Producer accuracy ： PA = (97/100) *100% = 97%

User accuracy：UA = (97/101) *100% = 96.04%

4. CONCLUSION

This paper is based on the GF1-16m wide remote sensing data and taking Taihe County in Anhui Province as the sample area. The corn, soybean, sweet potato and other major crops planting space distribution have been measured in Taihe County, based on the study of the regional phenological information and planting pattern, through the research on the distribution of crop remote sensing measurement process. Finally, three crops of corn, soybean and sweet potato in Taihe County were obtained, and the precision of the results was over 95% through precision evaluation. The results show that the spatial distribution of crop measurement method with remote sensing remote sensing has excellent practicability, standardization and high measuring accuracy. It can reflect the planting spatial distribution of crops in the study area, and provide practical and effective technological process and implementation plan for the remote sensing measurement of the spatial distribution of crop planting at the provincial level.

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