Research and Application of Remote Sensing Technology in Chinese Agricultural Statistics

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Abstract: Agriculture is the basis of national economy of China. Agricultural statistics is one of the key points of Chinese statistic work. Nowadays, the worldwide Earth Observation System (EOS) by Remote Sensing has been increasingly improved and the multi-temporal and multi-resolution EOS has been forming as well. The rapid development of Remote Sensing technology serves as the solid technological foundation for the in-depth application of Chinese agricultural statistics. This paper introduced the current situation of Chinese agricultural statistics and the achievement of each department on the statistic work of agricultural Remote Sensing. And the difficulties of Remote Sensing technology in agricultural statistics were also analyzed in terms of the situation of Chinese agriculture. Furthermore, the paper introduced the project of "National Statistic Remote Sensing Operational System Key Technology and Application" in particular, which is assumed by National Bureau of Statistics of China. The rural Earth sampling method and the technological course as well as the implementation scheme of the Remote Sensing survey on the planting area and yield of the main crops were elaborated. The current research development and application of the project were also involved.

Key words: Remote Sensing; agricultural statistics, crop, yield estimation, planting area

China is a big country of agriculture. According to the statistic data in 2005, the national total product of Chinese agriculture accounted for 12.5% of the national economy and the agricultural population was 72.6% of that for the whole nation [1]. Agricultural is not only the basis of the national economy of China, but also the basis of politics and society. Thus, the agricultural statistics is also one of the most important aspects of the statistic work of China. Since the reform and opening up, Chinese agricultural statistic work has been largely improved and provided favorable service for both China and the world. However, with the rapid change of times, the current method and technology of Chinese agricultural statistics cannot entirely meet the needs of the changing agricultural statistics in China. The brand new methods and technology are urged to be created. As an advanced technology to acquire information, Remote Sensing has special advantages in the field of statistics, especially in the agricultural statistics, and has got wide application in some developed countries. The national statistic Remote Sensing project has been developed by National Bureau of Statistics of China (NBS) with the purpose of applying Remote Sensing technology on the statistic work and testing the operational running system. This paper elaborated the current situation of Chinese agricultural statistic Remote Sensing application and the research work on agricultural Remote Sensing and statistics.

1. The current situation of Chinese agricultural statistics and the application of Remote

Sensing on agriculture

Chinese government always takes agriculture, country and peasants as a whole. Chinese rural statistics contains three index systems: agricultural statistics index system, rural statistics index system and rural residential statistics index system [2]. So far, China has established intact rural statistics team system and dispatched survey organization in each province (district, city) to manage and direct the survey team in each sampling county and each administrative level has its local statistic department. For a long period of development, Chinese rural area has been experiencing rapidly change, which leads to many new problems that agricultural statistics has to confront: the original pattern for data collection cannot entirely meet the needs due to the increasingly complex structure and the multiple survey objects; some statistic projects are unable to obtain accurate data by overall statistics; the aged survey samples are less representative for the collectivity; some contents and index in the agricultural statistics are left behind the current needs; the quality of the base statistic staff need to be improved and each system needs to be ameliorated.

As one of the three index of agricultural statistics, agricultural statistics also faces new challenge and pressure. More rapid and more accurate data would be needed in statistic survey; more holistic and in-depth analysis would be needed in statistic analysis; data management and statistic service needs to adapt to the mass storage and query technology and the spatialized data management technology; and the objective and timely contrast data would be also needed in statistic supervision. Therefore, to meet all these needs, new technologies must be introduced to each tache of the statistic work. At this point, the spatial information technology, Remote Sensing in particular, is one of the key support technologies, which is able to realize the technological improvement and the ideal innovation of statistic work, and an important guarantee to realize the transformation from conventional statistics to spatial statistics.

Remote Sensing technology has been successfully applied in a large number of fields since it developed 40 years ago. As a tool to acquire information, Remote Sensing has the advantages of objectivity, efficiency and wide coverage, which leads to its wide application in statistic field. Wide coverage can meet the needs of enlarging the statistic extension, conquering the influence of the natural environment and saving labor, financial and material resources. Moreover, objectivity helps avoid the disturbance from artificial factors and efficiency can meet the needs of timely statistics and statistics of emergent events. For the moment, there are many research and application on statistic remote sensing all over the world. Countries and organizations such as the United States, Europe and FAO have been working on the estimation of planting area and yield of the main crop since 1970s and have all benefited to certain degree. With the development and the spread application of remote sensing technology, the application of remote sensing in agricultural statistics has been increasingly characterized by operation and quantity and has drawn much more attention all over the world.

China started the work on agricultural remote sensing monitoring as early as the beginning of reform and opening up when Chinese scientists began to pay attention to crop yield estimation by remote sensing [3]. After many years' development, great progress has been made in agricultural statistic remote sensing in China. A lot of institutions have developed related research and built up a series of systems such as agricultural condition monitoring system and China Crop Watch System with Remote Sensing [4]. Many techniques, methods and experiences have been accumulated from the application of single remote sensing data to a combination of multi-source data, from yield

estimation of one type of crop to multiple crops yield estimation by remote sensing, from small district to multiple provinces and cities.

During the Seventh Five-Year Plan, metrological satellites had been successfully applied to the remote sensing monitoring and yield estimation of winter wheat by Chinese metrological department for the first time, and the dynamic monitoring and crop yield estimation system for Chinese northern winter wheat had been built up. This system has been running operationally at the National Meteorological Bureau since 1990, and its application has been extended to paddy, corn and other main crops for operation.

During the Eighth Five-Year Plan, Chinese academy of sciences, united with Ministry of Agriculture and other 40 institutions, developed testing research on large-area yield estimation by remote sensing for wheat, corn and paddy and built up large-area "experiment running system of yield estimation with remote sensing". A proportion of basic work on nationwide yield estimation by remote sensing has been finished. In 1995, the national resource and environmental database has been established based on information system and crop watch system. At the same time, a great deal of related research has been carried out in various districts such as East China, North China, northeast, and Jianghan Plain by many universities and institutes working corporately [5].

In 1998, Chinese academy of sciences prepared to construct China Crop Watch System with Remote Sensing. During the process of running, exploring, and developing, the testing work on nationwide yield estimation for each type of crop and the total grain yield had been gradually carrying on. And the monitoring scope has been expanded to the global scale since 2000. This system has been working for a long period, involving subsystems such as crop growth monitoring, yield estimation for the main crops, yield estimation for the main grain, spatial-temporal structure monitoring and the warning system for grain supply-demand balance [6]. Crop acreage monitoring technology using two individual sampling frameworks has been developed in this system, which well adapts to the characteristics in China. GVG crop type proportion sampling instrument has also been developed, in which the spline sampling frame has been built up [7].

The major operational work of the agricultural condition monitoring system established by Remote Sensing Application Center of the Ministry of Agriculture includes crop condition monitoring and yield estimation of winter wheat of China, remote sensing survey on planting area in the main cotton producing area, monitoring the planting area and forecasting the gross yield for corn and monitoring grassland resource. The monitoring theory is similar to that of MARS, that is, by crop identification on remote sensing images of sampling areas, the changing rate of crop in the sampling areas could be extracted, so that the crop planting area in the current year can be calculated according to the base data of the whole area in former years [8, 9]. However, the calculation accuracy of this method is largely depended on the historic base data. The uncertainty of the historic data limits the reliability of the monitoring results.

From 2003 to 2005, NBS united with Beijing Normal University to develop stage experiment on the operational running of multi-scale remote sensing survey on the typical crops (summer grain: wheat; autumn grain: corn and paddy rice) planting area in Hebei, Jiangsu, Anhui, Shandong, Henan, the results of which have been validated by the mass statistic sampling survey parcels from NBS. The work has made certain progress and established solid theoretical and practical foundation for the

establishment of the main grain planting area and yield remote sensing survey operational system.

Besides, many scientists have been working on a series of models such as the crop remote sensing model, paddy planting area and yield forecasting model, remote sensing model of winter wheat planting area and yield estimation, agriculture model, and corn yield estimation model and so on, which have got sound effect in reality [10].

However, many research works are still rest on the elementary phase and cannot be put into practice due to the limitation of the development of remote sensing technology and various other reasons. Besides, the key techniques in the operational running system such as the guarantee of remote sensing data requirement and the accuracy validation of the survey results have not been solved yet. Aiming at the current development of China and the world, National Bureau of Statistics of China developed the project of "National Statistic Remote Sensing Operational System Key Technology Research and Application" with the purpose of setting up the national statistical remote sensing information sharing and service platform, promoting the operation of Chinese statistic remote sensing information system, ameliorating the statistic methodology of the integrated census, sampling survey, statistic report, and spatial information technology application, improving the statistical data quality and service level. This paper is to explain the thought of research on agricultural remote sensing statistics on the basis of analyzing Chinese crop statistic work in existence.

2. Chinese crop statistics (the establishment and reform of Chinese rural statistics)

Nowadays, Chinese crop statistic survey contains investigation on planting area and yield of different kinds and seasonal crops, sampling investigation on crop planting intent, sampling investigation on the actual planting area of crops, sampling forecasting and field survey on summer grain, early rice, and autumn grain, collecting, coordinating, and compiling other related data, evaluating the quality of the major product yield data and developing analysis and research on the supply-demand situation of farm products.(Rural Statistic System of National Bureau of Statistics of China)

(1) Sampling frame of crop statistic investigation

857 sampling counties have been taken out in China in 1984, and then sampling villages are picked out from the sampling counties to establish the survey sampling frame. Up to now, the sampling frame has been changed in turn for three times. The samples now in use were extracted by integrated multiple types of sampling methods according to the first national agricultural census material in 1999. The sampled population is made up of 1/3 to 1/2 of (or all, if possible,) the primary units of rural administrative villages (residents committees) governed by the national sampling survey counties in principle. However, the sampling frame has become aged and less representative and the data is hard to be classified for use.

(2) Crop planting area survey

In the past, the crop planting area was reported by lower level administrations based on overall statistic method rather than an effective one. Recently, sampling survey has been carried out using index in the sampling frame materials which is related to the arable land planting area, the gross crop planting area, the planting area and yield of the major types of crops. In the first phase, Multivariate and Probability Proportionate to Size (MPPS) is used to extract sampling villages

(Multiple themes include plant area, major crop area); in the second phase, major crop planting area investigation is carried on according to the natural parcel in every sampling village. Investigators are dispatched to obtain the crop planting area data by field survey. However, the survey data has not been well applied due to the immature sampling survey method. Besides, it costs a great deal of financial and labor resources and long period of time to acquire data by field survey, and the data accuracy is hard to ensure due to various artificial factors.

(3) Crop yield survey
The work flow of yield survey is to extract villages from the national sampling counties, then extract parcels from the selected villages. The survey parcels are randomly picked out from all the parcels of each production season. The number of natural parcels for certain kind of crop survey in each province (district, city) is exclusive. Investigators randomly take out 3 to 5 small samples in the fields to survey. The yield of each type of crop is the arithmetic average of small samples. The problems of this method are basically similar to those of area investigation.

(4) Data report manner, survey, quality control, and management work
The crop statistic data is collected by report from lower administrative departments to higher ones, which is sensitive to the outside disturbance. Since 1999, the uniform computer super gathering program has been adopted in the sampling survey of summer grain, early rice and autumn grain to gather the field survey data and cancel the manual gathering at the country and county level, which help reduce partial disturbance.

Data quality control is very important and has always got much attention from NBS. Its work mainly contains establishing the standardized rules of basic work at survey net points and the operational criterion of sampling survey technology for investigators. The national government checks up the quality of base data every year. The spot-check at the national level means that the national government checks up provinces selectively, then counties examine themselves and receive data examination by their provinces. However, the accuracy and completeness of this work cannot be ensured due to lack of overall and accurate contrast data.

3. The research thoughts of crop remote sensing statistics [The implementation scheme of the project of National Statistic Remote Sensing Operational System Key Technology Research and Application]

Although crop statistics in China has the advantages of large-scale field survey team, the disadvantages such as the aged sampling frame, manual data collection, and less efficient data coordinating and processing, etc. Fortunately, the successful application of remote sensing technology in statistics inside and outside China provides us with valuable thoughts and abundant application experiences for reference.

Aiming at the characteristics of crop statistics in China and the prominent problems in current work, the national statistic remote sensing project carried out survey and research particularly on crop statistics, such as agricultural production seedling condition survey, crop disaster affected and suffering condition survey, arable land changing monitoring and survey, crop production trend forecasting, and the area and yield survey for different types of crop, hoping to solve some real difficulties and problems in arable land area statistics, crop planting area and yield statistics. Applying remote sensing technology as well as GIS and GPS technology to Chinese agricultural

statistics is of great significance to establish the Earth sampling system, to ameliorate the sampling survey method, to improve the representative of data, to reform the acquiring manner (including method, time and accuracy) of survey data, to realize the overall coverage of remote sensing survey on national crop planting area and yield, to promote the development to agricultural statistic technology, to ameliorate the statistic system, and to improve the quality of statistic data.

3.1 Establish the Earth sampling survey system

In the traditional statistic sampling method, the sampling method and the sampling frame are determined according to different administrative levels, which lead to problems such as less representative samples and difficulty in classified usage of data for some survey. To meet the needs of spatialized sampling during Earth sampling survey in rural area and to improve the original sampling method, National Bureau of Statistics of China has developed research on the Earth sampling method in rural area by integrating remote sensing and statistic sampling technology.

Under the precondition of ensuring the accuracy of statistic analysis, the 3S technology, which is employed to be integrated with statistic sampling to distribute the field samples, provides spatial sampling technology support for remote sensing survey on crop planting area and yield and the contrast between residential sampling and arable land and realize the interactive validation with the sampling survey technology in existence. Aiming at the major crop (wheat, corn, and paddy) and other related land cover types, the sampling and extrapolating method by remote sensing integrated with statistic sampling technology has been established and the sampling survey counties, villages, parcels have been appropriately distributed with the support of MPPS. Research on the Earth sampling method in rural area has been done to obtain field samples in thirteen main grain production provinces. And the rural Earth sampling unit base then was established in one or two typical demonstrate provinces. The sampling unit base mainly contains the spatial information of the Earth sampling units, the natural attributes information, the social attributes information of samples and the update and exchanging management of samples.

As for the implementation scheme of spatialized sample selection and optimization of the Earth sampling survey in rural area, the grid spatial Earth sampling method, the spatial Earth sampling method, the catalog sampling with spatial sampling method and the multilevel sampling method would be tested in order to set up the most appropriate Earth sampling system.

1) The grid spatial Earth sampling method

The grid spatial Earth sampling breaks the original pure spatial sampling with administrative boundaries. This method extracts Primary Sampling Units (PSUs) from grids in sampling provinces and counties, studies on sampling technology based on stratification and geologic statistics, and distributes the spatial Earth samples taking into account the influences of natural conditions such as rivers, mountains and other natural obstacles. Although, this method is relatively objective and can well reflect the changing of arable land and the planting area of crops, it brings certain difficulties to field survey.

2) The spatial Earth sampling method

Spatial Earth sampling is a pure spatial sampling method to maintain the completeness of the administrative boundaries of the secondary sampling units. This method reserves the completeness of the secondary administrative boundaries when designing grids during the research on PSU based

on both spatial base relief map and remote sensing images, studies on sampling technology based on stratification and geologic statistics, and distributes the spatial Earth samples taking into account the influences of natural conditions such as rivers, mountains and other natural obstacles. This method is relatively objective and can well reflect the changing of arable land and the planting area of crops as well as consider the difficulties in field survey.

3) The catalog sampling with spatial sampling method

The catalog sampling with spatial sampling method integrates the catalog sampling method with the spatial sampling method. Sampling administrative counties are firstly selected according to the catalog of administrative provinces, and then sampling villages are taken out from the catalog of administrative counties. The Earth samples are extracted randomly from remote sensing images on the basis the sampling villages.

4) The multilevel catalog sampling method

The multilevel catalog sampling is a traditional method based on administrative catalog. Sampling administrative counties are firstly selected according to the catalog of administrative provinces, and then sampling villages are taken out from the catalog of administrative counties. The Earth samples are extracted from the catalog of administrative villages. It would be more convenient to adopt some boundaries in common use such as ridges, rivers, roads, and villages.

On the basis of the established Earth sampling method, the field data gathering system would be studied on. The field data for crop planting area and yield remote sensing survey and the arable land contrast field data would be gathered by portable GPS. Spatial attributes of the field data would be increased and the burden on surveyors would be reduced. It will also benefit the monitoring work on the surveyors, accurately aim at and trace the survey objects, enhance the effects of statistic monitoring, and control the data quality.

3.2 crop planting area and yield survey by remote sensing

The important agricultural condition information, such as the changing of planting area, crop condition and the yield of the main crops, is the vital basis for the national government to establish grain product polices and economic plans. The crop planting area and yield survey with remote sensing technology can largely ameliorate the current traditional statistic technology and the manner of laying out products.

According to the needs of NBS for the statistic operation on the estimation on crops planting area and yield, aiming at the three kinds of main grain crops, namely, wheat, corn and paddy, the method integrating multi-platform and multi-scale remote sensing survey with mass statistic sampling was adopted to establish the “Grain Crop Planting Area Remote Sensing Survey and Yield Estimation Operational System for the National Main Grain Production regions” at the county, province and nation levels respectively by setting up a series of standardized criteria, testing study on technology and method, studying on representative application demonstration, and integrating the key technologies. The system has been prepared to be operationally applied to the thirteen main grain production provinces.

The main research contents are shown in Figure 1.

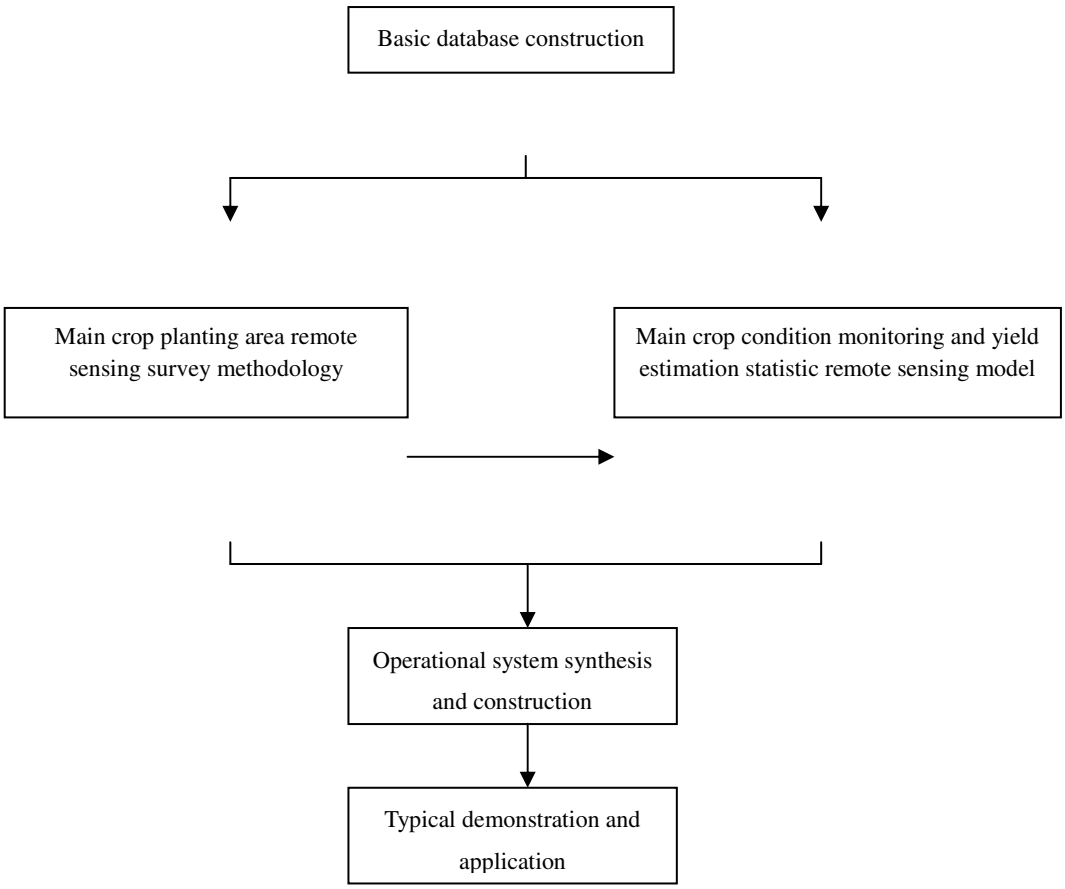

Figure 1. Research contents on crop planting area and yield estimation

1) Basic database construction

2) Research on the methodology of remote sensing survey on the main crop planting area

With the support of area data obtained from the mass statistic sampling Earth survey by NBS, a certain amount of test sites were selected from the main grain production provinces according to different planting structure to do research on the key technologies. The technological methodology of planting area survey for the main crops (wheat, paddy and corn) has been established by integrating multi-source remote sensing data with ground sampling survey. The research has been carried out on the following three aspects (Figure 2):

- Research on the technology and method of crop planting area survey at medium-high resolution
- Research on the technology and method of crop planting area survey at medium-low resolution
- Research on the method of paddy planting area survey with SAR remote sensing data at medium-high resolution

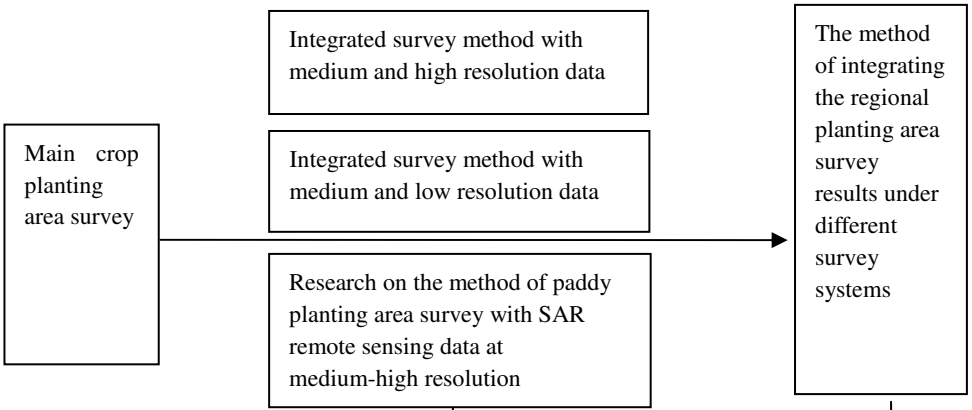

Figure 2. The methodology of remote sensing survey on the main crop planting area

3) Research on crop condition monitoring and yield estimation for the main crops
This research involves the Earth's surface parameters inversion and the remote sensing index calculation for remote sensing monitoring on crop condition and yield estimation, the remote sensing model of crop condition monitoring for the main crops, the research on the forecasting model for the yield of the main crops, and the system of integrated model of crop condition monitoring and yield estimation for crops. The remote sensing survey on crop yield estimation is to integrate the remote sensing technology and the statistics operational work, take medium resolution data as main data source as well as ground sample data, high resolution data and low resolution data for assistance, and estimate the crop yield for the whole country and provinces by integrating remote sensing model for crop yield estimation.

4) Research on the function and the operational flow of the statistic remote sensing operational system at the county, province and nation levels. Develop operational flow design, standard products design, thematic database establishment, study on the quality control, and set up the operational running system.

5) The demonstrative application would be firstly developed at the typical counties and typical provinces. On the basis of the typical testing region where the key technological problems have been tackled, the survey method would be ameliorated by integrating the technological method of crop area survey, crop condition monitoring and yield estimation in order to meet the accuracy needs of remote sensing survey on crop planting area and yield estimation. The design and establishment of the operational flow and running system would be tried on and be promoted to apply in the thirteen main grain production provinces.

3.3 Establish the National Statistic Remote Sensing Operational System

In order to extend the research accomplishment into operation in a larger area, the NBS will cooperate with the scientific institutions to further expand the fields in which remote sensing

technology integrates with statistic work and to establish the national statistic remote sensing operational system based on the research work in existence. Within the national statistic operational system, the self-contained national spatial statistic criterion standard, index method and technology system based on technologies such as the ground multilevel sample survey, remote sensing, geographic information system (GIS) and global positioning system (GPS), etc. would be established. Develop the statistic information base platform and the national statistic remote sensing information system operational running service. Make the modern spatial technology to be one of the key technologies to support the national statistic information development.

3.4 The problems in existence

A number of problems existing in the application of remote sensing technology in crop statistics need to be solved. These problems involves image interpretation technique, remote sensing data acquirement, field data collection, how to reduce the basic statistic work while improve efficiency, how to integrate different resolution data for use, the data insurance system, tech personnel training, method of remote sensing survey on crop planting area and yield, integration with GIS and GPS, and control of data quality and accuracy. The existence of these problems prevents the development of crop remote sensing statistics and further study is needed to solve these problems.

4. Introduction to the related work in existence

The National Bureau of Statistics of China united with some scientific institutions in China and widely cooperated with related international organization to try on the application of remote sensing technology in the field of agricultural statistics and has benefited a lot.

In 2001, according to the requirement of NBS, Zhejiang Province assumed the testing work on crop area sampling survey in the China-Korea agricultural statistic technology cooperation project. The results suggested that the crop planting area sampling survey method adopted by the work was scientific and easy to operate. It has provided with valuable experiences for the reform of arable land and crop planting area statistics and the research on the Earth sampling survey method.

From 2003 to 2005, NBS united with Beijing Normal University (BNU) to develop research in the Hi-Tech Research and Development Program of China (863 Program) to set up the standard, criterion and technique system for the main crop planting area survey by integrating multi-source remote sensing information and ground sampling survey information, and form a new sampling survey methodology with the integration of remote sensing and ground survey. The research on the application of satellite remote sensing technology in agricultural products yields survey had been developed in five provinces-Hebei, Henan, Shandong, Jiangsu, and Anhui and had received much achievement in this phase.

In 2004, NBS developed experiment research on winter wheat planting area survey by remote sensing in Henan Province. And the system was applied to establish demonstrative application for summer grain (winter wheat) and autumn grain (paddy, corn and cotton, research has been done to survey the cotton in the typical area) in five main grain production provinces-Henan, Hebei, Shandong, Jiangsu and Anhui in 2005.

In 2006, on the basis of summer grain (winter wheat) planting area survey by remote sensing in the

five provinces, NBS united institutions such as BNU and Institute of Regionalization of Academy of Agricultural Sciences to research on the techniques of remote sensing survey on the main autumn grain crop planting area in Pizhou, Jiangsu Province. Aiming at the technological difficulties in the autumn grain survey, this work has established the theoretical and methodological foundation for the operational running of crop survey by remote sensing and the statistic remote sensing project.

In 2006, NBS cooperated with the Ministry of Science and Technology to set up the vital project for the Hi_Tech Research and Development Program of China (863 Program)-"National Statistic Remote Sensing Operational System Key Technology Research and Application", which integrates the corporation of some institutions powerful at 3S technology. The project will be put into practice recently.

The base survey counties were equipped with GPS facilities twice in 2003 and 2007 respectively, which provides with filed facilities storage to realize statistic remote sensing operational running.

In 2007, Beijing Municipal Bureau of Statistics and the General Survey Team of Beijing in NBS cooperated with BNU starting the project of "Beijing Statistic Ecological Resources Remote Sensing Survey Running System" with the purpose of utilizing the advanced spatial information technology to collect and statistically process the area and yield index data of the green vegetation resources and the main crops in order to meet the operational needs of ecological resources statistics.

5. Conclusion and prospect

The application of remote sensing technology in agricultural statistics and even in the whole statistic system has become the keystone of the reform of statistic work in every country. NBS has developed certain amount of work on the application of remote sensing in agricultural statistics, which includes the establishment of crop planting area remote sensing monitoring technological criterion and application, summer grain and autumn grain planting area survey by remote sensing in the five provinces, etc., and has gained fairly good effects.

Due to the complexity and particularity of the agricultural statistic work in China and the limitation of remote sensing technology in China, some key technologies in Chinese agricultural remote sensing statistics have not yet been solved and the operational running system has not yet been formed. Therefore, taking the chance of the national statistic remote sensing, NBS will keep up cooperation with scientific departments and related international organization to develop research on statistic remote sensing technology, extend the practical application of advanced technologies in statistics, and make every effort to promote the development of statistic work.

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