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RS-GIS-GPS-Based Agricultural Condition Monitoring Systems at a National Scale

Yang Bangjie, Pei Zhiyuan, Zhang Songling
(*Chinese Academy of Agricultural Engineering, Beijing* 100026, *China*)

Abstract: China has a large population and limited arable land. It is essential to monitor agricultural condition, mainly annual farmland variation, crop condition and forecast grain yield for government decision making. In recent years, information technology has made considerable progress and 3S technology, Remote Sensing, GIS and GPS, have been used for resources and crop monitoring at a national or global scale. 3S technology based on agricultural condition monitoring systems at a national scale is introduced in this paper.

Key words: RS; GIS; GPS; agricultural condition; agricultural resources; crop condition; yield estimation
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1 Introduction

Agricultural condition monitoring includes agricultural resources and crop monitoring. The objective of resources monitoring is to monitor the quality and quantity of arable land and their changes. Crop monitoring is to monitor main crops acreage and distribution, crop condition, disasters and yield estimation. China has a large population and limited arable land. It is essential to monitor annual agricultural conditions for government decision making.

In recent years, information technology has made considerable progress and 3S technology, RS (Remote Sensing), GIS, GPS and Internet, have been used for resources and crop monitoring at a national or global scale. RS and GPS are used for data collection, GIS is used as a data analyzing center and Internet provides a very fast, convenient and economic method for information exchange. The decision making technology has a revolutionary on collecting objective, timely and regular information at a national scale. Today, crop condition and grain yield information is sensitive to the world grain market.

Development of 3S technology based agricultural condition monitoring systems at a national scale in the Ministry of Agriculture was introduced in this paper mainly based on the authors' three projects: (1) *3S-based resources and environmental information system for the Ministry of Agriculture* is supported by the Department of Science and Technology (1997～2000); (2) *A pilot project of national agricultural condition monitoring system for the Ministry of Agriculture* is supported by the Ministry of Agriculture (1996～1999); (3) *Crop condition models based on characteristic papameters of NDVI (Normalized Different Vegetation Index)* is supported by National Natural Science Foundation of China (1999～2001).

2 3S-based Agricultural Resources Information System

2.1 Resources and Environmental Information System for the Ministry of Agriculture (AgriRIS)

The objective of this project is to develop an information system using RS and GIS, to collect arable land information and statistical data to

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Biographies: Yang Bangjie (1948-), Ph. D., professor, vice president of Chinese Academy of Agricultural Engineering. Email: bjyang@agri.gov.cn; Pei Zhiyuan and Zhang Songling, senior engineer.

provide the government with agricultural resources and environmental information for China's sustainable agricultural development.

2.2 The Technical Index of AgriREIS

The Information System with a scale of 1∶250 000 at a national scale and 1∶100 000 in some development areas such as Beijing-Tianjin Metropolitan Area, Yangtze River Delta and Zhujiang River Delta areas using Landsat TM data. The land use was identified as 28 categories[1].

2.3 The Information Demand of the Ministry of Agriculture

The Ministry of Agriculture needs resources and environmental information for:

1) Quantity of farmland, grassland and potential land for agriculture; 2) Variety of land use such as crop structure or changes to other use; 3) Quality of farmland such as pollution, salinity, desertification and fertility.

Some information cannot be obtained from satellite remote sensing, additional information comes from traditional statistic information collected by field investigation.

2.4 Information System Design[2]

The system was designed as a GIS based information system (Fig. 1).

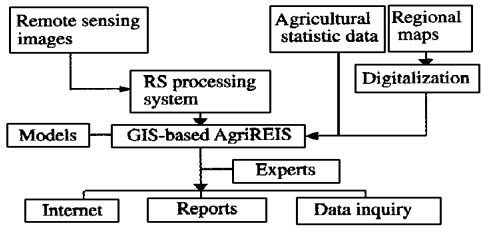

Fig. 1　The structure of the resources and environmental information system for the Ministry of Agriculture

1) Data resources: data come from remote sensing, agricultural statistic data and historical information.

2) GIS based information system: GIS was used for data storage, integration and analysis for decision making.

3) Information release: The information was summarized in thematic maps, reports for government and a part of information is released on the Internet for the public.

2.5 Decision Support System

The decision support system was organized by models, information and experts' experience[3]. Experts do the decision analysis with survey data and images from the GIS based AgriREIS. The reports are sent to related departments of the Ministry of Agriculture. The system can support reliable and timely information for government decision making.

3 3S-Based Crop Monitoring System

3.1 Ground Monitoring System

Traditionally, there is a ground monitoring system all over the country organized by the Ministry of Agriculture. Every county has an agricultural monitoring office in the local government. They collect crop information such as crops acreage, field management, crop condition, disasters and production, as arranged by the Ministry. The advantage is that complete data can be collected, but there are obvious shortcomings: 1) Subjectivity: the information is collected by many people all over the country with their own judgements, it is difficult to do this to the same standard; 2) Timeliness: collecting information from field and sending it to central government is a time consuming work; 3) Limited area coverage: collecting crop information is limited to a small number of points because of time and money restrictions. With information from limited points, it is impossible to draw a crop condition map of China.

3.2 Crop Monitoring Using RS

1) Objectives and advantages

Remote Sensing is used for crop monitoring including crop distribution, acreage, growth condition, disaster and yield estimation. The advantage of RS monitoring is to collect the whole country's information quickly, objectively and economically. Some information must be obtained from the ground such as disease, and in some areas

it is difficult to get images because of clouds. Crop monitoring needs ground information support.

2) Advances and problems

In 1980s, RS was used for crop monitoring in United States and European countries. From the Sixth Five2Year Plan (1981～1995), yield estimation using RS was the key state research project supported by the government. However, there was no operational system at a national scale which could be used by the Ministry of Agriculture. The reasons were: 1) Technical problems: in China, because of small2scale family farms and mixed crop systems, it is difficult to analyze even clear images; 2) Financial problems: expensive images are needed for an operational system at a national scale, especially for monitoring paddy fields, expensive radar images are needed; 3) Organizations: researchers think more in terms of academic achievements, not operational systems for the Ministry of Agriculture.

So, integrated information from RS and ground monitoring are needed for the Ministry of Agriculture, not only RS. Operational systems are different from academic achievement, therefore government and research institutes need to cooperate.

3.3 3S-Based Crop Monitoring System

The objective of this project is to develop a national crop monitoring system integrated with remote sensing and ground monitoring.

1) Technical approaches

The guidelines of the system design are: 1) crop condition monitoring and yield estimation at a national scale; 2) economical and timely operational system; 3) integrated remote sensing and ground monitoring.

In European countries, yields have been estimated by modeling the unit of production and measuring the crop acreage with a high spatial resolution remote sensing. This approach has problems of high cumulative error and expense. Another approach is to use high time resolution image NOAA data to estimate yield, this method is suitable for national scale and low cost, the problem is that it is difficult to measure acreage.

The main ideas of this research are: 1) the priority is for crop acreage estimation, because sown area is the first step to guarantee grain production; 2) Crop condition monitoring is useful for government to guide agricultural management and early yield estimation, and also suitable for RS monitoring; 3) Yield at a national scale will be estimated by cumulative NDVI model and ground information. The technical approaches are to develop crop condition and yield estimation models using cheap and high time resolution NOAA data, to rely on support from the ground monitoring system, and to use a GIS as a data analysis center with a land use information system AgriRIS (Fig. 2).

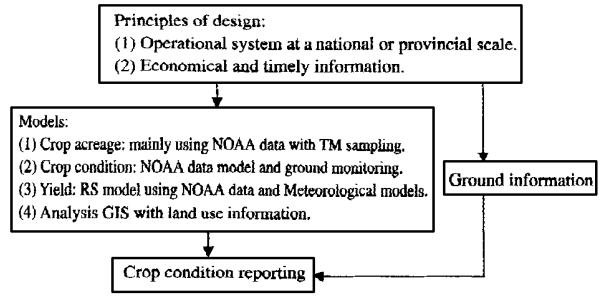

Fig. 2 Technical approaches for crop monitoring

2) Design of crop monitoring system

(1) Function of the system

The functions of the system include: crop identification and area measurement; crop condition monitoring; disaster monitoring; and yield estimation.

(2) System structure[4]

The structure of the system was designed as in Fig. 3 including three models: RS2GPS based data collecting subsystem; Internet based communication system; and GIS2based data processing, analyzing and reporting system.

3.4 Definition and Monitoring of Crop Condition

1) Definition of crop condition

In the late 1970s and early 1980s, considerable research efforts were focused on the use of

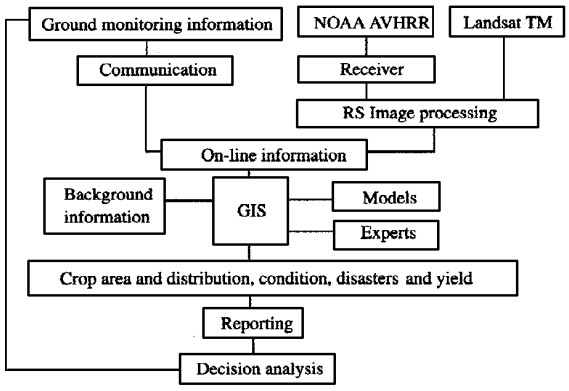

Fig. 3　3S2based crop monitoring system

multispectral images for crop inventory and crop production in USA. In 1990s, they were changed to precision crop management[5].

From the 1980s, yield estimation using remote sensing was researched for about twenty years. But actually, crop growth condition and tendency monitoring, namely crop condition monitoring, is the most important task for agricultural remote sensing applycation. The objectives of crop monitoring are (1) to support crop management; (2) for early yield estimation. There are no clear definition for crop condition and no standard calculation method for remote sensing monitoring. Crop condition models based on characteristic parameters of NDVI is a research project supported by National Natural Science Foundation of China (1999～2001). The objective of this research is to give a scientific definition, to develop RS models and standard measurement methods for crop condition.

Crop condition means crop growth condition and tendency, and can be described by individual and community characteristics. Good crop condition is considered as a crop community with a group of healthily developed individuals. The individual characteristics can be described with stem, leaf, root and ear's conditions. Crop community can be described by the community's density, distribution and development. Leaf Area Index (*LAI*) is a comprehensive parameter related to individual and community characteristics[6].

2) Approach of monitoring using RS

LAI can be measured by RS. *LAI* is a comprehensive parameter related to crop condition and can be measured by RS. All plants need sunlight for photosynthesis and try to get more energy from sunlight. That is why *LAI*s are very close each other in the same growth stage. *LAI* can be measured but the individual and community characteristics still need ground observation.

NDVI is a commonly used RS parameter related to *LAI*, growth stage and biomass. The approach for crop condition monitoring using RS is to measure *LAI* and estimate the crop condition by models integrated with *LAI* and information on the growth stage observed on ground (Fig. 4).

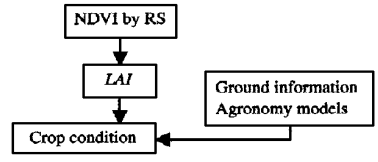

Fig. 4　Approach of crop condition monitoring

3) RS models of crop condition

There are two kinds of RS crop condition models. One is for crop condition evaluation and another for diagnosis.

Evaluation models include the following two kinds of models[6]: comparison year by year and grading models.

The evaluation models are used for early yield estimation and diagnosis models are used for field management. Diagnosis models include crop growth stage, fertilizer and water conditions, disease and insects, weeds identification , etc. Only NDVI is not enough for diagnosis models, a group of parameters, or a vector, is needed to model the situation[6].

4　Conclusions and Prospects

1) Operational monitoring methods development has been paid more attention to in this research. 3S2based resources and crop monitoring systems at a national scale are developed and used

in the Ministry of Agriculture

2) Development of crop diagnosis models is a challenge for agricultural RS scientists as the same situation in precision agriculture.

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基于 3S 技术的国家级农情监测系统

杨邦杰, 裴志远, 张松岭

(中国农业工程研究设计院, 北京 100026)

摘 要: 中国人口多、耕地有限, 农情信息主要是耕地与粮棉作物生产的信息, 对生产管理与政府决策是至关重要的。农情监测的主要任务是监测耕地的变化, 粮棉作物的面积、长势、灾害与产量。由于信息技术的发展, 3S 技术, 即遥感(RS), GIS 与 GPS 技术, 已用于国家与全球尺度的农情监测。该文介绍了作者近年来承担国家与农业部的科研项目而开发的农业部农情遥感监测系统与信息服务系统。

关键词: RS; GIS; GPS; 农情; 农业资源; 作物长势; 估产