ROLE OF REMOTE SENSING IN
ACHIEVING NATIONAL FOOD SELF-SUFFICIENCY
AND FOOD SECURITY

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KEY WORDS remote sensing; food self-sufficiency; food security

ABSTRACT This paper seeks to explore the role of Remote Sensing in solving the agriculture related problems, which are the basic issues of sustainable development.

1 Introduction

In recent years, more and more people in the world have taken the issues of sustainable development of society as their main focus. As every one knows that the earth now supports nearly six billion people, and human populations are growing at 1.5 percent per year or three people per second. Nobody knows how many people the earth can sustain, some guess eight billion, but others say nearly double of that. No matter how many people can be squeezed onto this planet, however, there are limits to the renewable or nonrenewable resources needed to support them. Efficient management of renewable resources and judicious use of nonrenewable ones, as well as improved conservation and protection of fragile and endangered environments, depend upon timely information acquisition and accurate analysis of them.

The agriculture problem is one of the basic and important issues of sustainable development. Society requires better knowledge about the geography-related agriculture resources and their condition, such as the available area of arable land and its distribution, the crop type classification and crop condition assessment, the land degradation and soil erosion and their control, as well as the agriculture-related natural disaster monitoring and evaluation etc.

As a modern technology for the earth observation and information acquisition, and especially when it integrates with the Global Positioning System (GPS) and Geographic Information System (GIS), Remote Sensing (RS) can play a big role in solving above mentioned agriculture-related problems.

2 Progress in Remote Sensing technology

Since 1960's, great progress has been made in the field of Remote Sensing after undergoing a long process of exploration. From experiment stage to application popularizing; from single discipline to the integration of multiple disciplines; from static state to dynamic development; from local region to the global range; from earth surface to the outer space, all above aspects have already shown the fact that the Remote Sensing technology has been developed into a quite mature stage. Besides, we have also realized that successful application of RS can greatly benefit from the integration of multi-discipline, interrelated information acquisition and processing procedures. For instance, the integration of RS with GIS and GPS, the so called ‘3S’ technology, is one of the hot topics in the world today.
From the viewpoint of RS only, it is still undergoing a series of exploration and development. More and more RS satellites for various application purposes are being planned, licensed, funded and launched. Generally speaking, the development trend of RS mainly focuses on the integration of multi-sensor, multi-resolution, multi-spectrum and multi-time data sources.

2.1 Multi-sensor

Many new types of RS sensors are undergoing research, which forms the pattern that multiple sensors coexist and one satellite is loaded with several sensors. So far, the widely used sensors include: normal frame-format camera (information recorded with panchromatic film, multi-band photograph, true-color film, infrared-color film, ultra-red film, etc.), panoramic camera, infrared scanner, multi-band scanner, infrared radiometer, microwave radiometer, matrix camera, CCD line scanner, 3-line CCD scanner, side-looking radar and other synthetic aperture radar as well as laser statoscope. By the way, the Inertial Navigation System (INS) and GPS technologies are also merged into the RS platform, which makes it possible to obtain the position and attitude of the sensor in the moment of data acquisition.

2.2 Multi-spectrum

The modern RS sensors can cover almost all parts of the "atmospheric windows", for example, the optical RS sensor can cover visible, near infrared and short wave infrared area; the wavelength of thermal infrared RS can reach 8 ~ 14μm; the wavelength scope for microwave RS is about 1 ~ 100 mm. On the other hand, many new developed RS sensors have very high spectrum resolution, for instance, the fine divided spectrum of imaging spectroradiometer can reach the level of 5 ~ 6mm. On the Lewis satellite of America, 384 wave bands are defined within the spectrum scope of 0.4 ~ 2.5μm.

2.3 Multi-resolution

Here the multi-resolution includes space resolution, spectral resolution and temperature resolution. Take the space resolution as an example, the resolution span varies from 1.1 km for NOAA AVHRR, 80 m for Landsat MSS, 50 m for MOS-1, 30 m for TM and ERS-1, 5m for MOMS-02, 10 m/20 m for SPOT-1/2 (5m for SPOT-3/4). For Radarsat the space resolution can be 10 m, 28 m, 35 m, and 50 m/100 m respectively. For some lately launched satellites and those in schedule, the space resolution has already and will still be improved greatly. The RS data with multi-resolution make it possible to create the image data pyramid in order to meet the different requirements.

2.4 Multi-temporal

This characteristic means to obtain the image data for the same area repeatedly within certain cycle, which makes it possible to determine and monitor the changed area and their rules about earth surface in the systematic and dynamic way and over a long period of time.

2.5 Integration of RS, GPS and GIS

Here only a brief discussion is given about the possible '3S' integration modes in the application.

2.5.1 Integration of GIS and GPS

Using the eletronic maps of GIS and the GPS based real-time differential positioning technology, we can create various electronic navigation systems of GPS + GIS. This type of system can be applied to transportation, public security detection and the automatic driving of cars or ships. Also, we can directly use the GPS technology for the real-time updating of GIS. This is the most practical, convenient and unexpensive integration method. Several integration modes with different level of sophistication and price are available, they are:

1) Single GIS positioning + raster electronic map

This system can supply the real-time position of moving objects (e.g. cars, ships and airplanes) in order to support auxiliary navigation.

2) Single GPS positioning + vector electronic map

This system can automatically calculate and display the optimal route according to the position of target and the present position of moving car or ship in order to guide the driver to get to the destination in shortest time. Multimedia technology can be introduced during the guiding process.

3) GPS differential positioning + vector/raster electronic map

In this case, two GPS receivers are required for the fixed station and on the moving car or ship respectively, and the pseudo range differential tech-
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The position locating accuracy can reach ±1~3m. With the help of communication contact, this system can find application in transportation conducting, navigation and car’s or ship’s current situation monitoring.

The above mentioned GPS+GIS integration systems can also be used for farm crop cultivation and other agriculture related operations.

2.5.2 Integration of GIS and RS

RS is the important data source of GIS and the means of data updating, on the contrary, GIS can serve as the auxiliary information in RS data processing in order to help the automatic extraction of semantic and non-semantic information. Three possible integration methods of GIS with RS are shown in Fig. 1.

2.5.3 Integration of GPS/GIS and RS

The point determination of target in RS is usually dependent on the ground control points. If we want to realize the real-time point determination without ground control information, the RS sensor’s space position \((X_s, Y_s, Z_s)\) and its attitude \((\Phi, \Omega, K)\) in the moment of image acquisition will be obtained through the GPS/INS simultaneous recording.

At present, the dynamic phase difference method has been adopted in aerial/space photogrammetric triangulation, which is sometimes called GPS photogrammetry. Although the point determination process is not in real-time, but after a series of post-processing, the determination accuracy can reach the level of meter or even centimeter. This technology has already been applied in practical production.

2.5.4 Whole integration of RS, GIS and GPS

The whole integration system of RS, GIS and GPS has not only the function of automatic, real-time data acquisition, data processing and data updating, but also the ability to analyze and apply those data intelligently. The system can support scientific decision making and answer various sophisticated questions possibly arisen from users.

3 Role of Remote Sensing for solving agriculture related problems

When one considers the aspects involved in the worldwide supply and demand for agricultural products and how to solve the biological and technological problems faced by modern agriculture he will find out that it is an extremely broad problem intimately related with worldwide problems of population, energy, environmental quality, climate, and weather. These factors are in turn influenced by human values and traditions, and economic, political, and social systems.

How RS is used in agriculture is a quite large topic. In the following, only some main aspects are chosen for discussion.

3.1 Agricultural land resource investigation

Agricultural land or arable land may be broadly defined as land primarily used for production of food and fiber. A knowledge of available agricultural land area and land use is important for many planning and management activities concerned with the national food-sufficiency and food security.

Traditionally, the medium, small scale aerial photographs and satellite images have been utilized for agricultural land resource investigation, including
the land area and the classification of land coverage, etc. This information can be directly interpreted from appropriate aerial photographs or RS images, or obtained by means of digital image processing. When high accuracy is required, e.g., in the case concerning the owner of land, the rectified photograph and/or orthophoto should be adopted plus the use of ground control information. More recently, the integration methods of RS data with the GIS and GPS information are getting more and more consideration by people.

3.2 Crop type classification and crop condition monitoring

Crop type classification by Remote Sensing technology is based on the premise that specific crop type can be identified by their spectral response patterns and image texture. Successful identification of crops requires a knowledge of the developmental stages of each crop in the areas to be inventoried. Because of changes in crop characteristics during the growing season, image from different dates during the growing cycle can be very useful in the interpretation process. The use of multiband photograph provides advantages over the use of panchromatic one because of the increasing spectral information, and also, stereoscopic coverage provides the advantage of being able to use plant height in the discrimination process.

3.3 Crop yield estimation

Crop yield estimation based on RS has met with varying degree of success. In principle, the process is simple and straightforward. There is need to determine the area of each crop type and estimate the yield per unit area of each crop, then the total crop production is a simple product of the area times the yield per unit area. In practice, the process is complex, crop yield depends, among other things, on soil moisture, soil fertility, and air and soil temperature. In addition, yield can be selectively reduced by disease, insect infestation, and other stress-producing agents. Successful crop yield prediction should consider climatic and meteorologic conditions. This type of information can be obtained from meteorological satellite such as NOAA AVHRR data.

3.4 Soil erosion control

Soil erosion control is closely related to the management and development of agricultural resource. Besides the natural forces, such as the climate conditions, the wind and the hydrology factors, which will cause the soil erosion, it is also frequently suggested that human action is responsible for soil degradation and desertification. For instance, rapidly growing rural population, it is often argued, can lead to over-cultivation of land, with loss of fertility, declining crop yields and in some case severe degradation and erosion.

The inventory of soil erosion information can be obtained with RS technology. This information is quite useful in such activities as comprehensive land use planning. Understanding soil suitability for various land use is essential to prevent further environmental deterioration associated with misuse of land, and also it is the important guarantee for national food security.

3.5 Conception of precision agriculture

How can a nation produces abundant farm products to meet general social demands. One of the valid ways is to develop agriculture from a weak-quality industry to a highly effective industry. The key of this is to obtain precision information of farming and affect the process through the introducing of scientific methods and management.

The conception of precision agriculture refers to the multiple technologies of RS, GIS, GPS, computer, communication and network, automation, and the like effectively integrated with the subjects of geography, agriculture, bioecology and pedology, etc., in order to realize the real-time monitoring and information acquisition about farm crops, land and soil, and for further dynamic analyzing, planning, managing as well as decision making.

Precision farming problems are closely related to planning problems. In order to create a better Planning Support System (PSS), the changes of farm crops and the relationships between them and geo-referenced information must be positioned, recognized and understood.

An application system has been proposed by the author for the farm crops temporal arrangement project. The system under consideration consists of five major functional blocks:

- Data processing
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- GPS
- Data analysis
- Temporal arrangement
- Data base

In detail please see Ref. [1].

4 Achievements gained by WTUSM in recent years

Founded in 1956, WTUSM is a national university in China, which emphasizes the disciplines of surveying and mapping and encompasses other mutually supportive subjects in science, engineering, humanities and economics.

Presently the university has more than 1800 staff members, among whom over 600 are teaching faculty. The total number of students is about 7400 who are studying respectively in undergraduate diploma programs, or BSc/MA programs, or working for MSc/MA or Ph. D degrees, or conducting post-doctoral research work.

There are eight schools and two departments in WTUSM, in addition, also located on the campus are the National Laboratory for Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS); the National Research Center for Project Technology of Satellite Positioning System; the Wuhan Training Department of the State Remote Sensing Center of China and the China Center for Antarctic Surveying and Mapping, etc.

The University has particular strength and has undertaken a large number of research and development projects in the following fields, and whose results have been well accepted and marketed at home and abroad. These fields include:

- Spatial positioning technologies;
- Studies on the earth’s gravity field;
- Fully digital automatic mapping systems (Virtuoz);
- RS technologies and their applications;
- Graphics and image processing;
- Theories and applications of GIS (GeoStar);
- Theories and applications of the integration of RS, GIS and GPS;
- GPS aided aerial triangulation (WuCAPSGPS);
- Automation and integration of plotting and mapping;
- Precision engineering surveying;
- Thematic map design and production with artificial intelligence computer software development;
- Expert systems;
- Applications of new technologies in urban planning and management; and
- Surveying and mapping in polar regions.

5 Summary

Remote Sensing is a very important technology in sustainable development process, so far no other means can replace its role in the ability to obtain observing information about the earth surface.

The developing countries, like China and Zimbabwe, have the ability of regeneration through their own efforts to develop the application of RS, GIS, and GPS technologies, in order to serve for the social economy development.

The Chinese government and the WTUSM are willing to cooperate with any other countries or organizations to push the Remote Sensing technology developing forward together.

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Reference

1 Li D R, Guan Z, He X. Future research on application of GPS/GIS/RS for farm crops temporal arrangement. Geographic Information Sciences, 1997, 3(1,2): 1–6