A Web-based Agricultural Decision Support System on Crop Growth Monitoring and Food Security Strategies

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Abstract—Food shortage has been among the most threatening problems to the world since the beginning of the new century. And it means more to the countries with a large amount of citizens such as China. Chinese governments at different levels have been taken different kinds of actions to stabilize and increase the yields of grains. A major premise of making right decisions is the ability to accurately assess crop growth and food supply, and an scientific decision-making process to provide appropriate strategies or countermeasures based on them. This can be accomplished partly by using the decision support system (DSS) that provide accurate and detailed information about crop growth and food supply. In this paper, an agricultural spatial DSS (ADSS) frame was studied and developed to meet the increasing demands. The ADSS was aimed at suggesting efficient strategies for problems in crop growth and food safety as well as providing timely and accurate information about crop growth and food supply. The system, based on the spatial information technologies and crop growth simulation methods, contains three parts: (1) a spatial agricultural resources data warehouse has been constructed; (2) a crops monitoring and simulation package was studied and developed; (3) a spatial decision support package for food-supply security developed. The ADSS has been applied to the Northeast China and been proven to be a successful tool for crop growth monitoring and food security strategies.

Index Terms—Crop growth monitoring; food supply security; ADSS; Northeast China

. INTRODUCTION

The latest years has seen mankind confronted with the problem of food security worldwide. China, with 7% of total arable land to feed 22% of total population of the world, has long been a focus of public attention (Cheng, 2005a). It has always been, therefore, the primary importance among priorities for Chinese governments at different levels to keep national or regional grain balances of demand and supply among all the grain macro-management activities. While timely and accurate information about regional crop growth and grain production is among the premises of food (grain) supply security macro-management for the governments. Moreover, with the pace of the regionalization of the food production bases accelerating, the major food-producing areas is playing increasingly important role in the national food security system (Cheng, et al. 2005b). The capability to accurately predict the crop growth and food production in these districts can contribute a lot to better scientific decision-making on the food-supply security at regional and national level (Wu Bingfang, 2004).

The application of decision support system (DSS) in the fields of agriculture provides a new and efficient method for improving the management of regional food production mode and decision-making on the management of food security (Cao Weixing, et al. 2007). The space technologies such as RS, GIS, now increasingly powerful tools, give support to agricultural DSS (ADSS). Crop-growth monitoring with RS can monitor the growth of crops and predict grain production more objectively and rapidly. RS, thereat, become a fundamental component and tool of DSS. GIS, being powerful in the data compilation, storage, management and spatial analysis, are widely used as the platform of an agricultural DSS, various crop growth models, grain production estimation models and other models extend extensively the functions of the agricultural DSS. Furthermore, with the rapid development of internet/intranet technology, Web technology is growing up to a new branch in the development of ADSS (Mei Fangquan, 2003). The application domains of agricultural DSS are mainly restricted to a specific field (Rui Xijie, et al. 2005; Zhu Yan, 2004), while it comes to regional agricultural macro-management, little DSS research has been reportedly done (Zhao QianJun, 2005). This paper presents the development of a DSS for the macro-management of the regional agricultural activities and food security in Northeast China, which has been one of the key grain production bases of China. The proposed DSS has the ability to suggest solutions for common problems in agricultural practices, which include crops growth monitoring, simulation, grain production estimation and the macro-management of agricultural production activities and food security.

. THE STUDY AREA, RESEARCH SIGNIFICANCE AND OBJECTIVES

Northeast China has been being among the key food-production bases of China since the foundation of PRC, serving as one of the main sources of merchandized food supply for rice, corn, soybean. Northeast China is playing a increasing important role in food security with the situation of food security is getting worse. And it is also regarded as the largest strategic spare food base in China or a stabilizer of domestic food market (Cheng, et al. 2005b). The irrational agricultural land use structure, disarrangement of agricultural activities, unreasonable
dispose of crop planting structure and frequency of natural disasters, however, resulted in fluctuations of the regional dramatic grain production, hampering the development of the regional agricultural industry and threatening regional and national food supply security. More advanced methods and technologies are needed to manage all the information with different sources, and interruptedly analyze all the information to get better strategies for administration. An ADSS can, obviously, meet the needs. But up to now, there is no such decision support system available in the field.

The paper aimed at developing an ADSS dealing with the development of a DSS for crops growth monitoring and simulation, grain production prediction, providing the decision-making strategies and the early warning of food supply and the macro-management of agricultural activities for the agricultural administration in Northeast China. Therefore, the main objective is to develop a monitoring system for watching crop growth, finding problems in crop growth, selecting appropriate choices. To achieve this objective, the following tasks were accomplished:

1. Conducting an extensive literature review;
2. Interviewing experts in agriculture, information system;
3. Constructing the spatial data warehouse of agricultural resources in northeast China;
4. Experimental data were acquired by conducting a series of experiments, and then validated and modified with them the models from the literature or other source;
5. Developing crops monitoring, crops growth simulation and grain production estimation system;
6. Developing the DSS for food security in Northeast China (including the knowledge base and models base).

Number footnotes separately in superscripts 1, 2, ... Place the actual footnote at the bottom of the column in which it was cited, as in this column. See first page footnote as an example.

THE FRAMEWORK OF THE ADSS

Based on the characteristics of data and users, a mixed structure of the system was adopted which is a combination of B/S and C/S structure. The architecture of the system is shown in the Fig. 1, based on the traditional 3-tiers architecture of “browser/application server/database server, the application services is divided into two parts according to the logic functions of the system: application server and Web server. The B/S structure is made up of four components: Web browser/Web server/application server/database server. The Web browser brings users UI and transmits the requests from users; the Web server deals with and distributes the requests; database server provides data retrieval, storage, modification, etc; while application sever contains various models such as agricultural land use disposal models, crop growth models, grain prediction and estimation models, data access models, etc.

![Fig. 1 The framework of the agricultural decision support system (ADSS)](image)
For the system server or other special users, B/S mode may be less convenient and a bit slower, especially when processing a huge amount of images and other operational processes. While C/S architecture makes data processing and other operations run across multiple hosts and brings more efficiency and scalability to the application. In the paper, a C/S mode was added into the system’s architecture. The client-server applications in the paper are split into three components: the client component of the application requests or sends information to a central application server or database server, and then application server or database server deals with all the processes and returns the results to the client.

IV. DEVELOPMENT OF THE ADSS

A Construction of the spatial data warehouse of agricultural resources

The spatial database includes satellite RS images (Land sat TM, MODIS, AVHRR), statistical data (about the regional agricultural economic index, grain production, etc.), agricultural meteorological data, agronomy parameters, agricultural land resources, and data about the environment, information about the demand and supply of grain at various scale.

A database management system has been developed for the spatial data warehouse with the following operations: inputting, storing, managing, querying and indexing data in the data warehouse, regular spatial analysis with data, data and thematic map outputting and database maintaining.

B Development of the crops monitoring system based on RS and corresponding simulation models base

The system contains monitoring, acquisition, and simulation of crop growth and condition, and prediction of grain harvest based on RS. It consists of 6 components: crop condition monitoring, crop acreage estimation, crops growth simulation and yield prediction, grain production estimation, cropping index and crop structure monitoring, drought monitoring.

C Development of the ADSS for food security and macro-management of agricultural activities

1 Methods

The system was developed using a rule-based shell software available in the market. The basic building blocks of the decision support system are the rules. Rules
were made from the data available from the survey and the literature review.

The typical rules are generally composed of the following components:

Qualifiers: These are questions that the user is asked to provide answers to within an “If-then” frame. The value of the qualifier is fixed and cannot be changed.

Variables and mathematical models: Variables are created to accept input from the users while the mathematical models are used to evaluate and direct the decision process.

Choices: Choices are the product of specific scenarios in the decision support system. The recommendations at the end of a session are the choices. In the decision support system presented in this paper, many measures such as adjustment of agricultural land types, adjustment of regional corps planting structure and other macro-management measures of agricultural activities are the choices.

2 Contents of the Sub-DSS in the ADSS
The sub-DSS aimed at serving the management and agricultural technicians with decision-making choices. It includes the following components:

(1) Spatial decision support on the adjustment of agricultural land-use structures
This module is used for evaluating the adaptability of agricultural land resources with GIS, and analyzes the major factors to bring the environment ecological risks, and quantize the types, amount and spatial distribution of arable land which need to ex-farming.

(2) Spatial decision support on the adjustment of regional corps planting structure
This module analyzes information about the demand and supply of each kind of grain and predict the tendency home and abroad, and then evaluates the regional crops planting structure at present with RS monitoring of crops planting structure, and quantify the types, the quantity and spatial distribution of crop planting structure needed to adjust.

(3) Spatial decision support of macro-management of agricultural activities
This module analyzes grain production potentials with crop growth simulation models and GIS technology; it also analyzes quantitatively the types and effects of hazards which lead to underproduction of crop

(4) Early warning system of Regional grain supply risk.
Based on the early warning model of grain supply risk, it predicts the probable changes regional grain demand on the basis of the prediction of regional population changes and the grain production at different years, then evaluates the status of grain shortage, gives decision-making choices in advance.

CONCLUSIONS
A major component of an ADSS is the ability to accurately assess the condition of crop growth and food supply to provide appropriate strategies or countermeasures. This can be accomplished in part by using new space technologies such as RSGIS. A agriculture DSS for crop growth monitoring, simulation and food security was studied and developed. RS, GIS, crop growth simulation models and early warning model of grain supply risk were incorporated into the package of the system. These technologies and simulation models are discussed in the literature. Yet, a limited number of these methods are utilized together to serve regional micromanagement of agricultural activities.

The ADSS for crop watch and food security discussed in this paper was developed after: (1) Conducting an extensive literature review; (2) Interviewing experts in agriculture, information system, carrying out field survey of various agriculture zones; (3) acquiring experimental data by conducting a series of experiments, and then validating and modifying the models.

However, the system has still some limitations such as (1) limited statistical data about the crops condition and growth in the past years are included in the system’s database; (2) most of monitoring data are to be interpreted manually; (3) the scalability of models. The models in the system were only validated by the data from several spots (such as Hailun Station for ecological agriculture), but when they are used in other agricultural zones, deviations or errors will inevitably occur. More detailed validation should be done in the future work.

ACKNOWLEDGEMENTS
This work was jointly supported by Foundation item: national natural fund (No. 40401003), Scientific Research Foundation of Jiangsu Key Laboratory of Resources and Environmental Information Engineering (No: 20080202 ) and Key Items for Henan science and technology (No: 102102310364).

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