STUDY ON THE CROP CONDITION MONITORING METHODS WITH REMOTE SENSING

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ABSTRACT:

It is of great significance to obtain the crop condition information at early stages in the crop growing season. Sometimes it is even more important than acquiring the exact production after harvest time. Along with the development of remote sensing applications, satellite data has become the uppermost data source to monitor large-scale crop condition. In the last twenty years, more than a dozen of methods based on remote sensing data were developed to monitor crop condition in different countries and either the precision or the effectiveness of these crop condition monitoring methods has been improved greatly. Among these methods the mainly are: (1) Direct monitoring method with remote sensing indices, which monitor crop condition with indices such as NDVI or LAI according to its values. Usually the higher the indices are, the better the crop condition is. (2) Image classification method, which first did a supervised or unsupervised classification on the remote sensing data, then label each category as certain growth level with observed data of seedling's growing status which has spatial and temporal attributes. (3) Same-period comparing method, which could get the relative crop growing status for certain period by comparing the remote sensed data (NDVI, for example) of the period with the data of the period in the history (last year, mostly). In this method, difference and ratio are the indices mostly used. (4) Crop growth profile monitoring method, which is the contrast between year and year for crop growth profile and can reflect the crop growing continuance at time during crop growing season. Time series of NDVI during the crop season are used and crop growth profiles are formed by getting statistic of NDVI at certain scale such as a province. (5) Crop growing models method, this method use the crop growing model (also called crop growing modes) to simulate the growing status of crop and estimate the crop condition with the simulated result. These methods, along with their applications, are compared and analyzed and advantages and disadvantages of each method are supplied after comparing. As conclusion of the article, while the satellite data with high frequency and low spatial resolution is still the main data source, the method of crop condition monitoring with remote sensing data is developing in the following directions: (1) from qualitative monitoring to quantitative monitoring; (2) more and more indices such as LAI, TCI, VCI and NDWI are used to monitor crop condition in order to increase the monitoring precision; (3) some crop growing models which simulate the crop growing process are used to monitor crop condition; (4) GPS, GIS and RS data are combined to get a better monitoring result. The problems to be solved in crop condition monitoring models are also addressed.

1. INTRODUCTION

Agricultural activity is not only one of the basic activities of human society, but also the premise for the development of human society. Besides, it has close relation with the development and stabilization of nowadays society.

Large scale crop condition monitoring can provide decision-making information for the working-out of agricultural policy and commissariat trade. It is also the necessary premise for crop production estimation.

Monitoring crop condition with remote sensing can get the condition of cereal crop seedlings, as well as the status and trend of their growth. It also helps to acquire the crop production information (RAO M. V. K, Ayyangar R. S, 1982). Acquiring the crop condition information at early stages of crop growth is even more important than acquiring the exact production after harvest time, especially when large scale commissariat shortage or surplus happens. Acquiring crop condition as early as possible has great influence on the policy-making on the price, circulation and storage of commissariat (Chen Shupeng, 1990, Lin Pei, 1992, Sun Jiulin , 1996).

Regional crop growth estimates based on filed reports are often expensive, prone to large errors, and cannot provide real-time, spatially explicit estimates or forecasting of crop condition. Satellite systems provide temporally and spatially continuous data cover most of the globe using relatively few instruments. Along with the development of remote sensing applications, satellite data has become the uppermost data source to monitor large-scale crop condition. USDA of U.S. and VI of EU, as well as FAO, all have build their own crop monitoring systems based on remote sensing (Liu Haiqi, 1999, Rassmussen, 1997).

2. DEVELOPMENT OF CROP CONDITION MONITORING

2.1 Situation in the world

The use of remote sensing technology in crop condition monitoring begins in west developed countries, especially United States. From 1974 to 1977, United States Department of Agriculture (USDA), National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA) and United States Department Of Commerce (USDC) cooperated to carry out the "Large Area

Crop Inventory Experiment (LACIE)" program. In the program, the main monitoring crop is wheat and the monitoring area is United States, Former Russia and Canada. From 1980 to 1986, these departments cooperated again to carry out the "redirected from Agriculture and Resources Inventory Surveys through Aerospace (AgRISTARS)" program. After that program a global scale operational crop monitoring system was build in 1986. The system not only realized the crop condition assessment and production prediction for many kinds of crops (such as wheat, rice, maize, soybean and cotton) in United States, but also monitored the main food producing countries in the world such as Former Russia, Canada, Mexico, Argentina, Brazil, China, India and Australia. The running of the system gets great economic benefit for United States. After that, the Joint Research Center (JRC) of European Union built its own crop production estimation system through "Monitoring Agriculture with Remote Sensing (MARS)" program. The monitoring result of the system was applied in the common agricultural policy of European Union such as agricultural subsidy and the verification of farmers' declaration (MacDonald and Hall, 1980). In that period, the scientist s in the field through out the world focus on crop monitoring methods with NOAA/AVHRR and great progress was achieved (Roberto, 1993; Carlson T N, 1993).

After United States, countries around the world such as France, Germany, Russia, Canada, Japan, India, Argentina, Brazil, Australia and Thailand also started their own research in estimating crop production with remote sensing. In these studies, different crop yield models were built and different remote sensing data was used in the estimation of crop acreage.
When the research on monitoring crops with remote sensing maturated, countries and organization such as United States, European Union and FAO all built their own monitoring system and put them into operation. The system to monitor native crop condition of United States was run by National Agricultural Statistics Service of USDA and AVHRR/NDVI data was the main data source of the system. Foreign Agricultural Service of USDA and the 10-day composite meteorological satellite data ran the foreign crop monitoring system of USA and Land-Sat data was used in the system. Supported by MARS program of EU, JRC developed the operational crop monitoring system CGMS (Crop Growth Monitoring System) which can get the crop biomass through crop models with remote sensing data and meteorological data. The system not only monitors the crop condition but also predict the crop production in EU countries every month (Supit I, Hoojier A A, 1994). Now the CGMS was migrated and run in most of the EU countries (Wang Yuguang, 1999). UN FAO also monitored the global crop condition with the GIEWS (Global Information and Early Warning System on Food and Agriculture) developed by them self. The system used 10-day composite of SPOT/VEGETATION NDVI data and the data pre-processing was down with a self-developed soft named WINDISP. The monitoring area of the system mainly includes Africa, Asia, South America, Caribbean, etc.

2.2 Situation in China

China begin to pay attention to the crop production estimation with remote sensing as early as 1979 and the study on crop condition monitoring method with remote sensing began from the middle of 1980s.

After more than 20 years research, China has accumulated enough experience in method and system construction to build a global crop growth monitoring system. In this condition Institute of Remote Sensing Application (IRSA), Chinese Academy of Sciences, built a system that can monitor the global crop growth with remote sensing data. The system realizes the multi-scale global crop ocndition monitoring by using the global NDVI products downloaded from the net as data source and using two monitoring methods which are real time monitoring and crop growing process monitoring. The development of the system was finished in 2004. In 2005, the system was run at monthly frequency to provide crop growth information in 46 countries and regions to relevant ministries and commissions in China. (Wu Bingfang, 2004, Meng Jihua, 2007).

3. CROP CONDITION MONITORING MODELS

After more than 30-years' researches around the world in crop condition monitoring models, following crop condition monitoring models have been developed and they are:

3.1 Direct monitoring models

Direct monitoring models means monitoring crop condition by analyzing the relationships between direct remote sensing indices (such as Normalized Difference Vegetation Index, NDVI and leaf area index, LAI). In this kind of research, NDVI (Shi Dingshan, 1992), RVI (Ratio Vegetation Index), PVI (Perpendicular Vegetation Index) (Liu Kequn, 1997) and the reflectance of crop at different bands (Wang Yanyi, 1991) are all widely used.

Direct monitoring models has the merits of easy to use and need less data. But due to its short of theoretic foundation, this model is hard to use in large scale area or in complex area.

3.2 Classification model

Classification model usually classify the farmland into several categories according to their difference in reflectance at different bands. Then the relationship between classified farmland and the different crop condition observed in the field will be analyzed by analysis (such as regressive analysis). When the relationship was found the crop condition at different areas can be estimated with the classified remote sensing image. Both Supervised and unsupervised classification techniques were also applied in crop condition monitoring and were proved to have a good monitoring effect (Li Jianping, Zheng Youfei, 2001; Li Jianping, 2002).

Classification model has almost the same merit and demerit with direct monitoring models: easy to use but has no theoretic foundation. Besides, large quantity of observed crop condition data was needed to calibrate the classification model when this model was put into application.

3.3 Same-period comparing model

Same-period comparing models get the relative crop condition for certain period by comparing the remote sensed data (such as LAI, NDVI, etc) of the period with the data of the period in the history (last year mostly, or the average in history) (RAO M.V.K, 1982). In this method, difference and ratio are the indices mostly used. The monitoring result of this model can reflect the spatial difference of crop condition at different areas (Meng Jihua, 2007). Crop condition map can be made from the monitoring result, from which the user can see how much and where the crop conditions have either deteriorated, remained unchanged or improved (Wu Bingfang, 2004).

As new sensors were used, new remote sensing data was also used in same-period comparing model which had improved the accuracy of the monitoring result (Wu Jianjun, 2002; Liu Aixia, 2003). But this does not change the fact that same-period comparing model can only reflect the crop condition at a certain time, not mention that the monitoring result was susceptible to the change in crop phenology and crop planting structure which make it unsteady.

In despite of its disadvantage and limitations, this model was applied in most of the crop condition monitoring systems in the world which make it the most popular model in all the crop condition monitoring models (Liu Haiqi, 1999; Wu Bingfang, 2004; Zhao Yue, 2002).

3.4 Crop growing process monitoring model

High time frequency meteorological satellite can get the information of terrestrial process daily, which make it possible to monitor the crop continuously and dynamically. NDVI profile of crops can be formed by collocate the NDVI value along time lines; it can reflect the change of crop NDVI from planting, seedling, tassel, to maturation and harvestry. Different crops have different characteristics in their NDVI profiles, and even the same crop growing in different environments. So the crop condition and its growing trends can be obtained by analyzing the characteristics of its time series NDVI profile (Wang Yanyi, 1991; S. M. E Groten 1993; Jiang Dong, Wang Naibing, Yang Xiaohuan, 2002).

Crop growing process monitoring model, which is the contrast between year and year for crop growing profile, can reflect the crop growing continuance during crop growing season (Zhang Feng, Wu Bingfang, 2004). Time series of NDVI image during the crop season are used and crop growth profiles are formed by getting statistical average of NDVI in a certain region such as a province or a country. The crop growth of the year can be evaluated by analyzing the similarity and difference between the crop growing profiles of the year and the year in the history. According to the responding relationship between the curve and the crop condition, diagnostic parameters (eigenvalues) are extracted to estimate the status of crop growth, which realized the quantitative monitoring of crop growth.

Real time monitoring can show the spatial difference of crop condition at a certain period, while crop growing process monitoring can reflect the crop condition through the crop growing season.

3.5 Crop Growing model

Crop Growing models realize the dynamic monitoring of crop growing process by simulate the crop growing process with crop growing models. The fundamental idea of crop growing model is to reflect the crop growing process with mathematic formula. The drive of all the crop growing models is the interception of solar radiation for vegetation canopy and the photosynthesis that produce the dry biomass.

The most popular crop growing models include SUCROS (Simple and Universal Crop growth Simulator), (Modules of all Annual Crop Simulator), CERES (Crop Environment Resource Synthesis) and P-1/2/3, etc (Katawatin R, Crown P H, 1996; Carberry P S, 1989; Wu Y H, 1989; Hodges T, 1992; Xie Yun and Kiniry, 2002). Some of these models focus on the commonness of all crops while the other models focus on the specialty of different crops. In recent years, researcher in the field keep on working hard to develop new models such as ORYZA, SERES-RICE and SIMRIW, etc.

Crop growing models can actually reflect the crop growing process and monitor the crop condition accurately. Development of remote sensing technology and the use of remote sensing data make it possible to apply crop growing models at large scale areas. But the application of these models need lots of agro-parameters and the model must be calibrated by local field data to be run at different places. In some degree, the lack of local agro-parameters and observed field data, together with its complexity, put a limitation on the application of these models.

3.6 Diagnosis model

Diagnosis model assess the crop condition from the aspect of condition and environment that will influence crop growth. Factors considered in the model include crop phenology and its growing stages, fertilizing situation, water stress and drought assessment, happen of crop diseases and insect pests, spreading degree of weed, etc. The application of diagnosis model was mostly needed by field management. Ever since 1990s, researchers work on diagnosis model paid more attention to field fertilization and water situation than other factors, a lot of models were built to derive these factors that are needed by diagnosis model with remote sensing data and great progress was achieved (Wang Jihua, 2001).

Diagnosis model is one of the future developing directions for monitoring crop condition with remote sensing data.

4. PROBLEMS TO BE SOLVED

Although the development of remote sensing technology has bring a new opportunity for monitoring crop condition and a mass of researchers in the field have been working on it form more than 30 years, there are still some problems to be solved.

First of all, there is no clear definition for crop condition, or researcher in the field don’t have a consentaneous agreement on what the crop condition means. How could we monitor the crop condition when we are not sure what is exact the crop condition. So it is urgent to form a definition for crop condition. In author’s opinion, this should be done from the aspects of individual characteristic and colony characteristic of crops.

Then the researchers should focus on the development of quantitative crop condition monitoring models. Almost all the crop condition monitoring models existed are qualitative models among which few are quantitative or even semi-quantitative model. Quantitative model can give quantitative crop condition monitoring which will be more helpful to different levels of crop condition information users.

What’s more, the study on crop condition monitoring should be connected with the study on crop yield. Yield is the integrated result of crop condition at different periods and crop condition at each crop growing stage has its own way of influencing the final yield. Those who care about the crop condition care more about what influence will be inflicted on crop yield by the crop condition at the time. So the monitoring and assessment of crop condition also need to estimate its influence on crop yield.

Finally, the systematization for different crop condition models is also very important. It can increase the monitoring efficiency, lower the demand on personnel to do the crop condition monitoring and make the monitoring result more objective. After all, this can help more countries, departments, organization and individual to have the opportunity to use crop condition information.

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