An Operational State Land Use/Cover Monitoring System in China Based on Remote Sensing and GIS Technology

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ABSTRACT With support from national key science and technology program in 1996-2000, Chinese scientists in the field of remote sensing and GIS are carrying out the project of dynamic monitoring in national land use/cover change. One of the aims of this project is to establish the operational system of remote sensing monitoring covering all over china before the year 2000.

The key technical problems for the operational system include: the combination classification system of national land use and its environmental background based integrated of remote sensing and GIS technology ;the interpretation technique that classified and digitized of land use and environmental background information from Landsat TM images and other data sources using integrated RS and GIS system; the designing and establishing of background database which is important foundation for dynamic monitoring of land use change; the regionalization for Chinese farmland and urban land dynamic sampling; the dynamic index model of land-use and spatial statistical model for sampling study etc..

The establishing of operational state land use/cover monitoring system in China will not only be able to support the decision-making of national sustainable development, but also will make contribution to the study of global land-use and land cover change.

KEY WORDS China, remote sensing, dynamic monitor, operational system, land use/cover, GIS

1. Introduction

1.1 The Importance of Establishing the Operational State Land Use/Cover Dynamic Monitoring System Based on Remote Sensing and GIS Technology

All through the world, especially in the developing countries, the conflicts between the increasing needs for social and economic developments and the shortage of resources, the worse ecology environment make the social and economic improving in further face a plight situation. In addition, with the developing of social and economy and the growing population, the land use intensity and extension are becoming more significant. At the same time, however, the protective work on the resources and environment is not paid enough attention to, which all has involved potential destructive regional land cover, resources and environment problems. This has restricted the sustainable development of social and economy. It has become a key research project to resolve the question on how to find the developing pathway compatible with the natural environment which would protect and make better the resources and environment conditions when realizing the social and economy continuously development. To obtain the land use/cover dynamic information all around in time is the prerequisite to probe into the research project on global level which associated with the human beings sustainable development in the future.

Resent years, the economic development and the growth of population in China have put double pressure on the land use and land cover, which has brought out more influences on them than any time before. Land use/cover condition has important environmental meaning. The land use/cover change (LUCC) can degrade or improve the capability of continuous land using and the original cover's resuming. Sustainable development stratify require the government to make suitable decision on the sustainable land use management at macro-scale efficiently. Such as to guide and give administrative order to exploit the natural resources in right way not destroying the ecological environment. For this objective, the information on the farmland change, urbanization, deforestation and reforestation, desertification, water body dynamic and land degradation etc., should be acquired accurately in time to the government authorities. The information-obtaining problem has become the central attention of national decision making authorities and the scientist at home and abroad. Therefore, it is very valuable to use the remote sensing technique as main data source to provide the urgent needed information on land use/cover change to national decision making authorities to make scientific decision on land use management at multilevel, such as national integrated, regional and thematic areas.

1.2. The Existed Foundation and the Capability to Establish the State Operational Land Use/Cover Dynamic Monitoring Information System in China

Since 1970s, Chinese government and Chinese Academy of Sciences have organized many

surveys on land use, soil general survey and other special topics all over the country and carried out series of research work on regional environment at national scale. As a result, many land use/cover and environment background data sets had been accumulated. However, because of the problems on the different task and the scattered devises, the primitive communicative way and the inconsistency of data standard, the data sets are difficult to be systemized and so they can not bring into play its valuation thoroughly. Facing to the problems mentioned above, we need to preprocess the data sets and integrate them into the national information system with modern management. Then the organized data can provide efficient service for making strategic decision and project on our national and regional exploitation and developing with the land use/cover dynamic information obtained from remote sensing and GIS technology.

Through 20 years research work, remote sensing and GIS technology have been used in widespread area of our nation. A group of scientific stuffs were brought up and a systematic theory and methodology are built in this technology area. At the middle of 1990s, we had completed a large project successfully, which titled " Remote Sensing Investigation and Dynamic Study on Resources and Environment in China ", making use of the macro-scale, quickness and high accuracy virtues of remote sensing. It proves that we has the capability and foundations to establish our national "operational land use/cover dynamic monitoring system" based on remote sensing and GIS technology.

Land use/cover and the environment are always in dynamic process. After surveying on land use/cover all over the country at the first time, providing the dynamic information in certain period and renew the data in time is meaningful to the government. This project would meet the continuous information needs for making macro-scale decision support on sustainable land use management at state level.

1.3 The Objectives of the State Operational System

The project focus on establishing the state operational land use/cover dynamic monitoring information system so that it can improve the establishment and development of national integrated serving system basing on remote sensing. Through monitoring the change on land use/cover and environment over the whole country every five years and over typical area every year, the operational system should achieve the following objectives:

— to obtain and provide the dynamic information on main land use types such as farmland and urban land every year of the country as a whole;

— to obtain and provide the information on national fundamental resources and environment of which the agricultural resources as the main part, every five years;

— to obtain and provide the land use/cover and environment dynamic information of some key area with significant meanings to the whole country every year;

— to investigate the interrelationship between the land use and land cover and the driving force from human activity to LUCC, and assess the process of LUCC impacting on potential agricultural environment, further, forecast the change trends in the future;

— to establish state assistant decision support system on sustainable land use management, environment protection and agriculture sustainable development;

— to establish stable and integrated state operational land use/cover dynamic information serving system;

— to provide the internet service for national high level decision making authorities and other involved informative department in certain term and in emergency.

2. Principal Technique and Methodology

2.1. Combining Classification System on Land Use/Cover and Environment

According to the following considerations: (1) the work should be compatible with the international global change research projects, and (2) the thematic information needs for large area of land use/cover monitoring, and (3) accessibility from remote sensing data sets, the project chose land use/cover as main investigation and monitor object. At the same time, with the assistant from geomorphology map and climate data, the satellite image have be interpreted into primary geographic environment units at the same scale as the land use/cover map. Under the GIS working environment, these two types of classification system can be integrated to produce the land use/cover-environment combined classification system through overlapping the land use/cover data on the primary geographic environment unit. The realization of classification under GIS technology support can produce any kinds of combining maps and data on land use/cover and environment which clients need. Also, the clients can retrieve any kinds of environmental background on any kinds of land use/cover types. As a result, the operational system can meet multiple sides of needs from the different

clients on the resources and environment dynamic information.

Land use/cover classification system: Dynamics on land resource, including land use and land cover change, is the most direct imprints of humans activity on the nature. It is also the research area that can mostly represent the high priority of macro-scale and quickness character of spatial remote sensing technology. To counter the demands of macro-scale investigation for results data and remote sensing characteristics, land use and land cover types were classified two levels including 6 first level class types and 24 second level types. The first level types include farmland, forest, grassland, water body, resident and industrial site land, and others. The first level types are divided into 26 second level types based on the land cover character and the land use pattern of human beings. For example, the forest type is divided into forest coverage land, shrub land and others types; grass land is divided into high coverage grassland, middle coverage grassland and the low coverage grassland. This classification has great meaning to support further research work on plant cover change, land degradation and desertification.

Basic geographical environment classification system

In order to create environment classification system and further understand the relationship between land use/cover change and geographical environment background, the boundary of primary geographical units are drawn while remote sensing images are interpreted for land use/cover. Multi-attribute judgments of one unit are realized through matching remote sensing data with non-remote sensing data. The classification system is consisted 43 types and two levels.

a. Temperature: 9 classes are divided according to accumulated temperature index (>0 ℃);

b. Moisture Coefficient: 6 classes based on aridity;

c. Geomorphologic features: 4 types and 12 grades are divided by geomorphologic forms:

1.Mountainous land: 4 sub-types are divided according to relative elevation differences;

2.Hill land: 4 sub-types according to elevation;

3.Plat form : 4 sub-type according to plat form altitude;

4.Plain: 7 sub-types according to slope altitude and aspect

d. Soil texture: sandy, loam, and fine soil types are divided.

2.2. Overall Digital Working Environment to Build the Basic Database Using Integrated Technique of Remote Sensing and GIS

Under the overall digital techniques support, we have finished building the Landsat TM images database with imaging date at mid-1990s and land use/cover map at scale of 1:100,000 coving all though the country. During the image interpreting work, we thoroughly utilized the man-machine interactive priority to increase the classification accuracy through enhancing the image at the real time. Putting the image on the screen as back layer, the interpreter draw the object boundaries on the screen directly which were saved as vector format of data. Comparing with the traditional work style, at which the boundaries were draw on the photos and then digitized into computers, the overall digital working style can decrease the accumulated errors and labors. After the establishment of basic database by the experienced researcher, some interpreting standards and interpreting sighs with regional characters have been built. Depending on these experiments, we have built up the information extraction and applying model on selected GIS software platform. It is designed with so flexible interface that it can realize the synchronous management on the image data and the vector coverage and can be easily used by the operators after their short time's studying. This technique system can realize the information extraction and database renew at real time and increase interpreting accuracy on remote sensing image, which all would be the key technology bases on establishing the operating information system.

2.3. Dynamic Index on Land Use/Cover Change

Dynamic index system should be designed to describe the dynamic degree on LUCC in quantity. As to the farmland and urban land dynamics, an index named "farmland-urban dynamic degree" is made as following expression:

$$I_d = 100\% (|A_{fh} - A_{fn}|) / A_{fh} + 100\% (|A_{ch} - A_{cn}|) / A_{ch}$$

Here, A_{fh} is the farmland area at former period; A_{fn} is the farmland area at current period; A_{ch} is the urban, resident and industrial site land area at former period. A_{ch} is the urban, resident and industrial site land area at current period.

As to the forest and grassland dynamics, we emphasized not only to monitor the change in quantity, but also to the change on quality. Relaying on the environmental background data and DEM data which contains geographic form elevation and slope information, the project take the weight mean of the forest and grassland area change under different ecological environment background as environmental dynamic index on these types of LUCC.

2.4. Designation for Dynamic Monitor Sampling Scheme on Farmland and Urban Land Change

As the largest developing country with huge territory, China has amounts of land use/cover types and complex regional environment background. During the increasing development in industry, the high dynamics on farmland and urban land have been introduced. In order to meet the demands for continuous national economy development, the dynamic condition should be monitored. The traditional investigate way cost amounts of money and labors, the most important limitation is that it can not satisfy the accuracy needs and the time limit needs. Although the investigation based on remote sensing covering on the whole nation can satisfy the above needs, the image data are so expansive that we can not provide them all at every year. In addition, it is unnecessary for macro-scale investigation. So it is necessary to design a efficient spatial sampling scheme to deduce the general change condition accurately when investigating the sample sites. The traditional statistical sampling methods has some shortages in survey the spatial object, such as the large amounts of samples, the low accuracy etc., also the estimating process is not consider the spatial distribution character.

The operational project have designed a sampling scheme which consider the spatial remote sensing surveying character and the special land use/cover change condition in history periods to realize the monitoring work on farmland and urban land dynamic during the natural cycle.

The sampling scheme utilized the spatial statistics theory on the sample estimation, best samples chose, and the sampling accuracy pretest. The main part of the scheme include: zoning on land use/cover dynamics based on the farmland and urban land change condition; distributing the sampling sites relaying on the multi-layers dynamic spatial sampling scheme according to the division of basic sampling unit on farmland dynamic degree in the former period.

The sampling and estimating process can be represented as follows (figure 1):

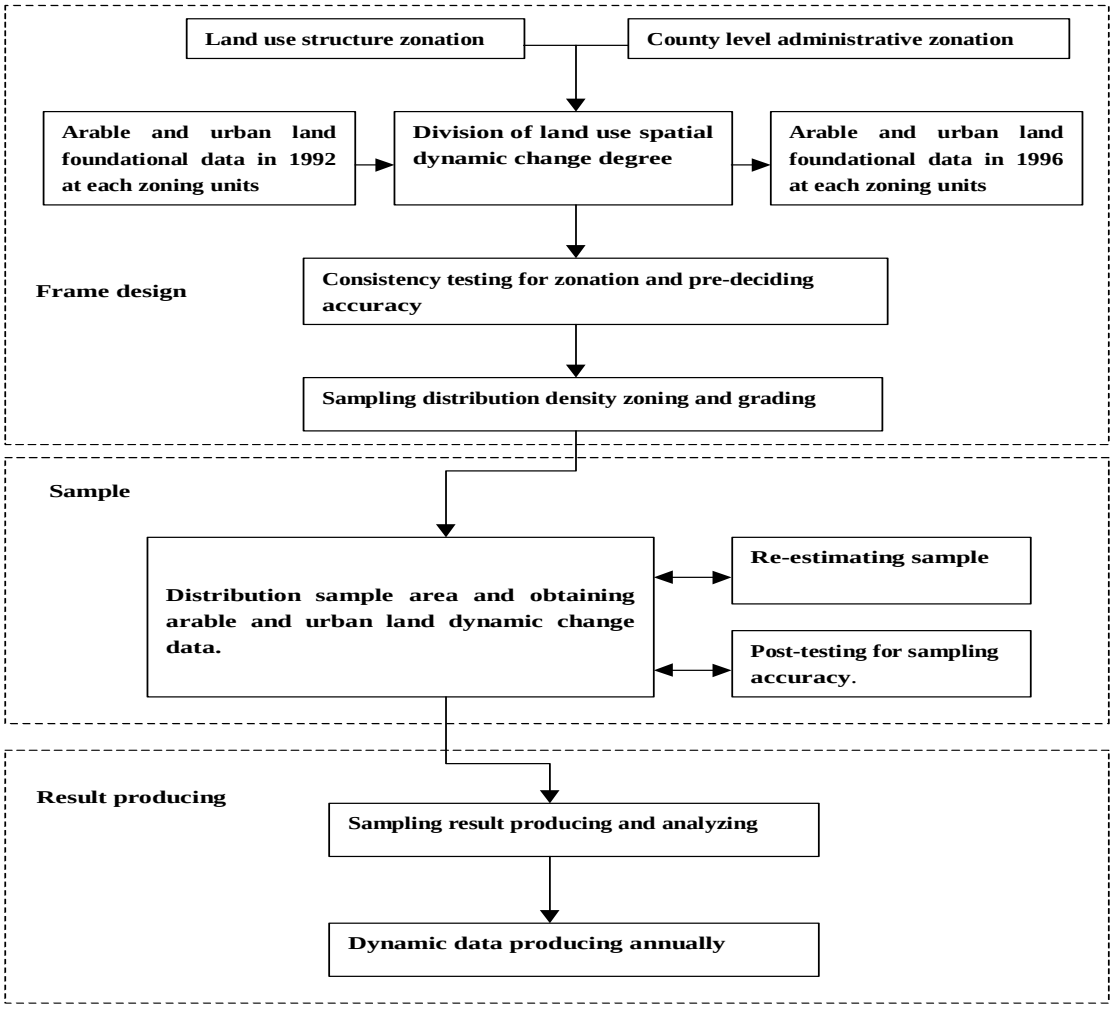

Figure 1 Dynamic sampling frame design and the technical procedure map

— to overlay the land use structure zonation on the county level administrative zonation to produce the primary sampling units layer;

— to produce the dynamic zonation units according to the farmland and urban land dynamic degree during the beginning of 1990s to the mid-1990s;

— to simulate to chose samples in each zone with stratified random sampling and to estimate the change degree in order to obtain the errors distributions when using different number and different sites of samples. According to the pre-requirement for estimation accuracy, we make decision on the sampling frequency;

—.to investigate the sample units every year by interpreting the Landsat TM image covering the area. The dynamic degree map on the samples units during this period would be produced by comparing the land use/cove map at this period with the former one;

— to estimate and summarize farmland and urban land dynamic degree and their area in each report unit applying the traditional stratified random sampling ratio estimation, in further, estimate the errors possible distribution range;

— to apply the spatial statistical interpolation method to estimate the dynamic degree in non-sampling units. Through this process, the farmland and urban land dynamic conditions could be estimated in each basic sampling units.

2.5. Key Monitoring and Investigating Area

As to the significant land use/cover and environment change phenomenon that would produce intensive impact on our nation's sustainable development, the operating system would pay more attention. The interactive processing mechanism between land use/cover change and the environment change, especially the human activity's driving process on LUCC should be investigated in further.

The monitor emphasizes on the following aspects:

(1) Changes in urbanization and basic farmland resources dynamic;

(2) Forest dynamic;

(3) Lake dynamic;

(4) Desertification dynamics in semi-arid and arid area.

According to the regional differential distribution characters on land use/cover and environment, the project performs different emphasis in monitoring and analyzing in six zones of China:

(1) Northeast of China: forest cover, farmland and the wetlands dynamics;

(2) North China: It is the most farmland centralized and the most significant of its change zone in China in resent years. The farmland and urban land dynamic in this zone and the grassland dynamic in inner Mongolia would be the monitoring emphases;

(3) Northwest China: desertification dynamic, soil elusion and land degradation;

(4) Southwest China: the farmland dynamic on high slope of mountain area;

(5) Central China: water body, farmland and forest dynamics; seek the suitable way to protect the environment for preventing the flood hazard in middle reaches of Yangzi river at land use/cover aspect;

(6) East China: urban and transportation land expansion dynamics; the exploitation on beach; reclamation situation on hillock and hill area;

(7) South China: farmland and urban land dynamic, especially the reclamation on hill area.

2.6. The Structure and Output of The Operational System

The being established state operational land use/cover dynamic monitoring information system contains the following sub-systems: remote sensing image data processing and analyzing system; main operating system and departmental and regional information systems.

Sustainable land use management has three levels. They are household, regional and national levels. The main data source in this monitoring system is Landsat TM image that has 30 meters of ground resolution, which had determined that they would be served for regional and national level of land, use management. It just meets the objective of the project. Multi-level outputs can be produced in this system, including primary, basic and high-level outputs from statistic survey data to data analyzing report and decision making support advises. The primary output contains the new TM image data and the land use/cover change maps in sample units. Basic output includes the change area in each region with different land use/cover types under different environment background. Also, the possible influence on environment and economic development by the LUCC should be assessed in quantity or in semi-quantity. High-level information output is produced to serve for national decision making authorities. In these type of output, the macro-scale LUCC information on the whole country and the advises reports on state level land use management according to the benefit principle for the nation as a whole would be offered in time relaying on the decision support system. All the

outputs can offered as report papers, figures or as files transmitted through the internet. Besides the operational system offers the dynamic information at certain intervals, some information requirements in emergency can also be provided in 24 hours from image processing to finishing the analyzing process and the final result.

3. Discussion

Among the national key research projects on remote sensing area, it is the first time to put forward to establish state operational land use/cover dynamic monitoring system. In order to ensure the realization of the system objectives, we must have a clear understanding on the kernel of the project. In other words, we must know about the technical requirements for a stable operating system at state level. The understandings includes:

(1) Not only the technique pathway and operational system can be put into practice, but also they can operate in continuous way. This need every procedure on the work flow have multiple ways to be done. For example, when the main satellite image data source can not meet the needs on some investigating area, there must has substitute to ensure the operating of the system;

(2) The system is an engineering project. When the system designer is absent, the operator can make the system running in stable depending the operational hand book and the flexible interface. This requirement needs the system designers write series of operating standards and handbooks in detail and design a flexible operating interface to make the operators familiar with the system easily. Comparing with other remote sensing project, the above requirements are the vital part which determine the fortune of the system;

(3) A general research project only care about the data to be used in this area, and its result is one-off. By comparison, the operational information system take charge of the quality of the continuously obtained data, analyzed results etc.. Otherwise, the clients, including the national departments and regional administrative authorities, will dispose of the information service. So, a spatial dynamic database in this system should be built not only can accurately represent the national land use/cover dynamic on spatial distribution characters, but also can accurately represent the temporal dynamics. All information and analyzed result should depend on the database.

Beyond all doubt, the establishment of “operational state land use/cover dynamic monitoring system in China bases on remote sensing and GIS technology” will play an important role on supporting national sustainable land use management when entering 21 century.

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