

LANDUSE RS MONITORING IN CHINA

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Commission VI, WG VII /3

KEY WORDS: Remote Sensing, land Use, Monitoring, Change Detection, Extraction.

ABSTRACT:

Following rapid development of economy in China, great changes also take place in landuse status, especially in the urban area. In order to quickly and truly acquire the information of landuse changes and status in quo, aid the government to scientifically manage the land resource, National Land and Resource Department executes a Landuse RS Monitoring project that began from 1999 and will keep for 12 years. Based on RS data of multi-sources, multi-resolutions and multi-phases, 93 important cities with more than 500,000 populations are monitored using advanced 3S technologies.

The article introduces the key technologies of landuse monitoring, including ortho-image production, change automatic detection and fusion methods of multi-sources RS data, etc.

The article focus on describing the working flow as below: (1) Choice of RS data: how to choose the best data from multi-source, multi-resolution and multi-phase RS data for different aims; (2) Processing of RS data: introduces the rectification model, GCP distribution rule and fusion method for different RS data; (3) Detection and extraction of changes: introduce the automatically change detection methods, and semi-automatic change extraction methods; (4) Investigation in the field: introduces the aim and means for investigation in the fields; (5) Post-processing. In order to get high quality production, the article also gives the reasonable precision indices for key steps.

Finally, the article points out the problems and gives the prospect of this project.

1. BACKGROUND

The economy rapidly develops in China these years, great changes of landuse status take place, especially in the urban. Most of changes are at the cost of occupation of agriculture land, which is the important base for China that is severely shortage of agriculture land but with great population.

In order to protect agriculture land and control the city growing, aid the government to scientifically manage the land resource, it's very important to quickly and truly master the landuse changes and status in quo.

In 1999, National Land and Resource Department executed a Landuse RS Monitoring project that will keep for 12 years. In this project, 93 important cities with more than 500,000 populations are monitored with advanced 3S technologies.

In the 5 successive years from 1999-2003, more than 250 times for monitoring 93 cities are finished (figure 1); and more than 20 units, including academies, institutes and companies, once took or are just taking into this task.

2. WORKING AIM

Based on RS, GIS and GPS technologies, combined with the experiences of six years in landuse RS monitoring, the aim of this project is to construct a nationwide landuse RS monitoring system, which is an systematical engineering integrated the administrative management, function mechanism and technology, and should be satisfied with mass production.

In the frame of this system, the important objects are as below:

- Monitoring landsue change, especial the increase of construction land and the occupation status of agriculture land by construction land.
- Updating landuse map with high-resolution image.

Except that, the status of urban development and base agriculture land protection are also the monitoring objects, further it can be used to check and aid land conversion and registration work for local government in land management.

3. KEY TECHNOLOGIES

Different applications require different data sources and technologies; therefore bring on corresponding technical standards, production precision indices and others. This article will give a detail description about RS technologies and working flow in landuse monitoring (see appendix 1).

3.1 Choice of RS data and auxiliary materials

RS data includes various satellite images and aerial images; auxiliary materials include topographic map, landuse map and DEM, the first two can be used as control material and also be the reference for information extraction.

This project studies on better choice of RS data from multi-sources, multi-resolutions and multi-phases satellite data

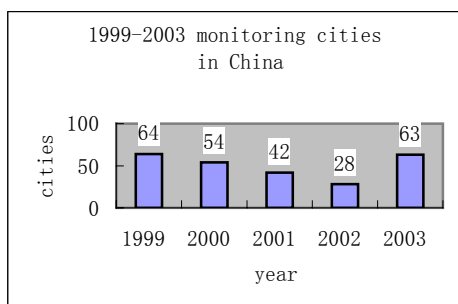


Figure1. 1999-2003 monitoring cities in China

and of control materials, according to working aims.

3.1.1 Medium-resolution satellite image: Viewing from the government demand on macro strategy in land resource, medium-resolution satellite image, such as TM, CBERS, SPOT2/4, IRS and KOMPSAT images can be optional. Refers to the table1, better choice would be TM and SPOT2/4 with lower cost, better image quality, robust programming function and good service.

Data	Resolution (m)	Revisit Period (Day)	Swath (Km)	Price (Scene)
TM/ETM	15/30	16	185	380/500\$
SPOT2/4	10	2-3	60*2	1000\$
CBERS	20	3-5	113	
IRS-1C/1D	5.8	5	70	
KOMPSAT	5	2-3	17	

Table 1. Comparison of medium-resolution satellite images

1:50,000 geographic map with 10m planimetric precision and 1:50,000 DEM with precision of 4-19m (plat-mountain zone) in elevation are the good auxiliary materials for rectification of TM/ and SPOT2/4.

3.1.2 High-resolution satellite image: With high ratio of capability-price as table2, SPOT5 2.5m image is preferred to be selected for updating 1:10,000 landuse map among the various data sources of SPOT5, IKONOS, Quickbird and aerial-photo,etc.

Data	Resolution (m)	Revisit period (day)	Swath (km)	Price (km ²)
SPOT5	2.5/10	2-3	60	2.41€
IKONOS	1/4	2-4	11	30\$
Quickbird	0.6/2.8	1-6	16	30\$

Table 2. Comparison of high-resolution satellite images

GPS control point with precision in cm level is the first choice as GCP for rectification of SPOT5, except that, 1:10,000 geographic map can be also optional.

1:10,000 DEM is good auxiliary material for image rectification, especial for image with mountain zone, but it is difficult to obtain widely, so 1:50,000 DEM can be as the substitute for rectification of SPOT5.

3.2 Processing of RS data

Rectification model, GCP number and distributed rule, fusion method can be introduced separately in this chapter.

3.2.1 Rectification model: There are several models for image rectification: physical model, polynomial model and rational function model.

Physical model: Constructs the strict model with the parameters of satellite and sensor, it requires DEM and fewer of GCP, can greatly decrease the workload and increase the precision of rectified image. PCI, Erdas, and other softwares can provide physical models for SPOT and TM/ETM.

Polynomial model: Simulates terrain form only with GCP, no

needs of the parameters of satellite and sensor and DEM. This model can be optional for plain zone.

Rational function model (RFM): Helps accessing to high precision by simulating camera model without parameters of orbit and camera. It is just for the satellite that can't supply the parameters but with complicate model.

The following table 3 lists the first two models in different softwares for satellite images of TM/ETM and SPOT:

Software	TM/ETM	SPOT 2/4	SPOT 5	Quikbird IKONOS
PCI9.0	1+2	1+2	1+2	3
ERDAS6.0	1+2	1+2	1	3
GEOIMAGE4.0	1	1+2	1+2	
ENVI4.0	1+2	1+2	1+2	3

Table 3. Software and models (1= Physical model, 2=Polynomial model, 3=RFM)

3.2.2 GCP number and distribution

GCP number and distribution seriously rely on rectification models.

Physical model: In theory, 16 GCP is enough for TM and 6 for SPOT; but in fact, number of GCPs is higher with different terrain conditions (plat.vs.mountain) and different softwares, for ex, 12-20 GCP is better for SPOT.

GCP is necessary to give a well-proportioned distribution and control four edges in image, just as in figure2 (red marks).

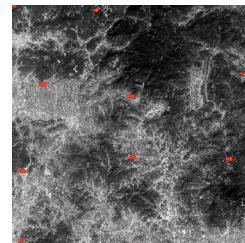


Figure2. distribution of GCP

Polynomial model: GCP number varies greatly with terrain: it is enough to have about 10 GCP in plat zone, but in mountain more, the number should be up to 20-50 GCP.

It is necessary to give an equal distribution for GCP in rectified zone; besides, in order to increase mosaic precision, common GCPs are needed in the joint zones of different rectified ranges.

3.2.3 Rectification and Match: In this article, rectification is special for the geometric processing of pan image (P), and match is for Multi-spectral image (M).

GCP, topographic map can be control materials for the rectification of pan image, and rectified pan image can be good reference for Multi-spectral image.

In general, pan image is firstly proceeded, then Multi-spectral image. But for the data with same acquiring condition (same satellite, orbit and VOF, etc.), for ex, SPOT5 programming data, it is possible to match Multi-spectral image to the raw pan image at first, then merge them, finally rectified fusion image with control materials. Rectified images will keep their original resolutions.

In order to control the geometrical quality of DOM, technical indices are needed as below:

RMS of GCP: An important but never unique index to control geometric quality in the process of DOM production, it can be produced when rectification model calculates with GCP. RMS value varies with softwares even for same image and same GCP.

Geometrical precision: An important index for DOM quality, it is checked with the high precision points from the field with GPS or other means.

Type	DOM precision
TM/ETM	Plat: 30m Mountain: 60m
SPOT2/4	Plat: 10-20m Mountain: 30-40m
SPOT5	Plat: 7.5m Mountain: 15m

Table 4: Dom precision

3.2.4 Image fusion: In order to get the best production enriched with geometric and spectral information, it's very important to give a better combination for P and M images from many resolution images, and better fusion methods.

Image combination: There are many kinds of combinations for fusion of P&M images, but it is suggested that the ratio of P&M image is better no greater than 4 times, for it's difficult to get a good geometric match for P&M and fusion results is not good if resolution ratio is too large. So the combination with * mark in table 5 is preferential:

Pan M	TM/ETM	SPOT2/4	SPOT5
TM/ETM	*	*	
SPOT2/4		*	
SPOT5			*

Table 5. image combinations

In this project, TM (M) + SPOT(P) and SPOT5 (P+ XS) are the popular combinations.

Image fusion: It is required that P&M images keep same resolution for fusion, generally Multi-spectral image is resample to the resolution of pan image. General fusion methods include Principal component analysis, HIS and Brovey, etc. these methods can be chosen according to the different image combinations or object characters. Figure 3-5 lists the fusion results with 3 fusion methods; it is obvious that HIS and Brovey methods are more effective for construction.

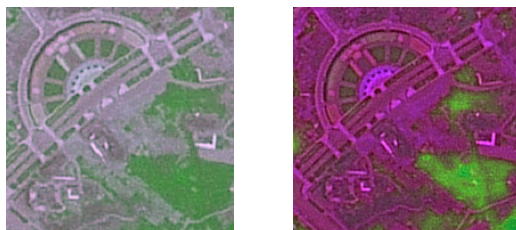


Figure 3. Brovey method

Figure 4. HIS method

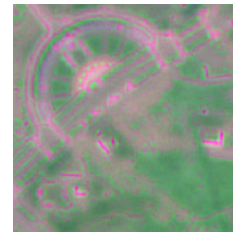


Figure 5. Principal component analysis method

3.3 Detection and extraction of changes

Landuse changes can be derived in two ways: comparing satellite images in two phases (image-image) or satellite image and landuse map (image-map). It's always a bottleneck to automatically detect and extract change no matter for image-image or image-map.

This project will focus on studying methods for detecting change information; at the same time, it will also introduce some methods for the change extraction.

3.3.1 Image-image: Spectrum aberrance method, Principal component difference method, subtract method, bands combination method and others can be used to show change for two-phase images. Among them, spectral aberrance method and subtract method are more popular because of they are easy to manipulate and the results are obvious.

Spectrum aberrance method: Fuses pan image of second phase and multi-spectral image of first phase, change information can be remarkable with special spectral information. See figure6 as below (red arrow).



Figure 6.Spectrum aberrance method Figure 7. Subtract method

Subtract method: Using the second-phase image subtracts the first-phase image with their gray value, white parcels in figure 7 is the potential change information. But these two methods are only effective for new growing construction land that has obvious change in gray value.

3.3.2 Image-map: For color landuse map with each kind of color represents one landuse type, it can be fused with image, the objects with abnormal spectrum maybe are change information (see the red arrow in figure 8):



Figure 8. Change detection for image-map

For landuse data with topology in vector format, it can be done just as color landuse map, only after it is colored for each landuse type.

Change information will be extracted by threshold value or other methods, but it is often mixed with noise and needs interpretation by human-computer interactive. Finally they are digitized into vector data and endowed with corresponding attribute, such as record number, area, coordinate and so on. Softwares as ARC/INFO, ARCView, ERDAS or MAPGIS can be good choices.

3.4 Investigation in the field

Investigation in the field is an important means to assure the quality of results.

3.4.1 Aim: (1) verify change information: check each change parcel if truly or false, acquire its true area, range and landuse type; (2) complete missing change; (3) measure DOM precision; (4) correct administrative boundary and toponym, etc.

3.4.2 Means: In order to decrease workload, three means are adopted. (1) Indoor processing with auxiliary materials supplied by the local government, including landuse map, landcover map and so on; (2) Querying into the responsible or technician of local government; (3) Checking on the spot for the change parcels that can't be solved by two means as before. In the investigation, it is good way to keep a computer that take all data, if no, it is necessary to print image and table in paper.

3.5 Post-processing

According to the results in the field, false change parcels are deleted, inaccurate polygons and types are corrected, each change parcel is given with new attribute, including landuse types before changing and landuse type in status, etc. Finally, they can be mapped into different kinds maps with needs or integrated into landuse database.

4. PROBLEM AND PROSPECT

4.1 Problem

4.1.1 change information automatic extraction: (1) image-image combination: some methods are conservatively effective to automatically extract change, but they have to deal with too much noise to obtain real change, also the vector data is not ideal after raster-to-vector conversion because of discontinuity or roughness; (2) Image-figure combination: there is no effective way to get change automatically at present.

Landuse status occurs great change these years since economy develops rapidly in China, National Land and Resource Department is just executing a plan to update landuse map with satellite image during several years, so it is urgent to find an

effective way to solve this problem.

4.1.2 Investigation means in the fields: For the reason of cost and technology, most of fields works are finished by traditional measure means to get area, width and other information of change parcel. In order to improve the precision of investigation result, it is suggested to use GPS and other new technologies in the fields.

4.2 Prospect

In the frame of nationwide land & resource investigation plan, this project will be with great potential in the future: (1) more and more new applications will be developed: except landuse change monitoring and landuse map update, it can be also used to construct and update the landuse database and cadastral database, aid landuse plan, land conversion investigation and cadastral management, supervise the development of national important engineering projects, monitor the development of disaster and provide strategies for disaster prevention, etc...

Following the developing of application, new data sources and new technologies will be required. For ex, in order to monitor the important construction project, the high-resolution satellite image will be used (just as QB and IKONOS). In 2004, aerial photography will be widely applied in cadastral map updating and database construction, especially after integrating with IMU/DGPS, digital camera and other new technologies.

(2) More and more cities will be brought into this project. At first, project focuses on 93 cities with more than 500,000 populations, then it will cover more cities, since there are 34 provinces or municipalities, 332 cities or autonomous states, 2860 counties or districts in China.

(3) More and more government departments and other branches will participate in this project: the project firstly services for center government to supervise the landuse status in macro dimension, then the local government of provinces or cities will forwardly apply this technology in their daily work since they have acknowledged its benefits. More and more needs will promote the developing of technologies, in reverse, new technologies will popularize and deepen the applications. In virtue of this trend, the project will construct the nationwide landuse RS monitoring system.

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Appendix 1: Working flow of landuse RS monitoring.

