USING 3S TECHNOLOGY
IN CHINESE INVESTIGATION OF LAND USE CHANGES

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ABSTRACT:

Land resources have alternated dynamically due to the national economic development during the last more than 30 years in China. The information on the extent and spatial distribution of various kinds of land use is essential for the decision makers or planners to find the rules of changes and take the feasible actions for the optimal development of land use. So, a project on investigating all kinds of land use and making statistic report forms and maps has been kept on by three levels of land use departments which are National Land and Resource Department (NLRD), province land departments and county land departments. All of the statistic reports and maps should be submitted to NLRD before Oct.1 each year.

Because of the poor technology and methods, the original processing flow was tedious, time consuming and expensive. But these problems have been improved by integrating GPS, GIS and RS (3S) technology recently. This article will introduce several issues about using the new technology to carry out land use investigation within a county. One of the key points is how to choose a set of data resources feasibly and economically. The next key point is how to use different data resources to find change information in doors and check them on the fields, and then five recommended schemes will be given a detailed account in this article. Furthermore, an experiment and our own corresponding software package suitable for land use investigation within a county is also introduced at the end of the article.

1. INTRODUCTION

How to use land resources reasonably and availably is one of the most important problems for each country, especially for China - the developing and agricultural one. Chinese government carried out a project to investigate land-use situation around the whole country from 1984 to 1994 in order to get real and certain land use statistical data and maps. That project had spent almost 10 years. A serials statistical data had been obtained about each spot, every village, every county, every province and even the whole country. And also many kinds of scale maps had been produced. The maps scale range was from 1:10,000 to 1:500,000. The investigation results had been very helpful for the government to make decision at that time.

But it is obvious that land is changed dynamically. In order to obtain the detail change information during every two years, another project had been started up to investigate the land use change annually from 1996 till now.

Most of investigation work was completed manually with the common method and technology at that time. It was time-consuming and labor intensive. So, a modern method and technology is needed to make land use investigated more quickly and easily.

Fortunately, with the development of computer application, software and internet technology, an advanced land use investigation technology has been studied based on GIS, GPS and RS integration. This new technology made the job more rapidly and efficiently.

But there are still many problems, for example statistic data standard has not been unified to the same format. In order to resolve these problems, unified software suitable for Chinese county investigation should be studied and developed as soon as possible. Data resources selection, RS image otho-rectification, change information detected and surveyed with GPS, statistic report and land use maps making could be integrated together by this new technology and software.

The main objective of this article is to introduce investigation procedure and software using "3S" technology. An experiment about this technology will be introduced at the end of this article, too.

2. METHOD

The modern approach of land use investigation includes three main steps: (1) change information extracted using RS and GIS technology, (2) data collected out of door using GIS and GPS technology, (3) data post-processing using GPS and GIS technology.

2.1 Change Information Detected and Extracted

Using RS and GIS technology can lessen workload of information detection and extraction since large amount of changed spots can be detected by computer or interpreted by human using remote sensing images, especially when high resolution images can be obtained and processed better and better now. Generally speaking, when images' geometrical resolution is higher than 2.5m like SPOT5, IKONOS and QUICKBIRD, and otho-rectified with strict physical model, their geometric accuracy can reach the demands of mapping scale 1:10000 or larger scale land use map. The main technique includes the choice of most suitable data resources, images and

maps rectification or matching, change information extraction.

2.1.1 Data Resources Collection: Several kinds of data may be used in landuse investigation, such as satellite images, aerial photo images, control materials, land use maps or land-use database and etc. But how to select RS data feasibly from so many kinds of images is one of the most important items in this study project.

Chinese counties are classified into four classes by analyzing each county's topography feature, economy development structure, area or range, and other attributes. Which kinds of RS images can be selected for some county land use investigation has been concluded in below table 1.

County class	County character	County Area	Examples	Recommending Images
First	Economy developed most quickly Land use changed most quickly	$<300Km^2$	Beijing, Shanghai, Most of Province Capital	Ikonos, QuickBird
second	Economy developed more quickly Land use changed more quickly	$300\text{-}1000Km^2$	County or city lies on the sides of main traffic, and etc.	Arial Photo images
third	Traffic inconvenience Economy undeveloped Land use changed slowly	$1000\text{-}3000 Km^2$	Guizhou Province, West of Xichuan province	SPOT5
Fourth	Fewer residence, Land use changed scarcely or hardly	$>3000Km^2$	Qingzang tableland, Basin of Caidamu	ETM+

Table 1. RS Images Recommended for Different County

2.1.2 Change Information Detection and Extraction: There are five schemes on detecting land use change with RS technology according to which kinds of images data can be obtained around the same area. Scheme one is having both history and current year high resolution images. Scheme two is having history and current year middle resolution images. Scheme three is having current year high resolution images and history middle resolution images. Scheme four is having history high resolution images and current year middlle resolution images. The last scheme is having only current year high resolution images.

Image \ Scheme	High Resolution Image		Middle Resolution Image	
	History	Current	History	Current
1				
2				
3				
4				
5				

Table 2. Different Schemes for Different Images Obtained

How to process these images and which kind of GPS will be used for different schemes will be talked about at the following content.

Scheme1- Having Two Phases of High Resolution Images: One of the two phases of images must be otho-rectified to the geodetic coordinate system with control materials firstly. The other one are matched to it. Then change information can be detected by overlaying them together. Images resolution is higher enough that its geometric accuracy can fit the needs of

scale 1:10000 land use maps. But its land use category can not be identified perfectly right. So, one of investigation tasks on the fields is to make up the omitted change spots, and the other main object is to check the spots category identified right or not. Navigation GPS with less than 10m precision will be ok.

The advantage of this scheme is that almost all of the change spots can be detected in doors and the geometric accuracy of their borders is suitable for mapping. But the shortcoming is that it will spend more money and time to buy and process images.

Scheme2-Having Two Phases of Middle Resolution Images: Images processed flow also includes otho-rectification, matching and overlaying. The difference is that land use maps will be rectified and overlayed on these two phases of images. Because of limited by images' resolution, the geometric accuracy of changed spots border are not so good enough to satisfy with the needs of scale 1:10000 map. So, many small change spots may be missed. At this time, the main object of investigation on the fields is to obtain spots' border coordinate surveyed with DGPS (Difference Global Position System) technology. And their attributes like land use category should be inquired as well.

This scheme gives a good advice that using cheaper middle RS images to find change area and surveying their border points' coordinates with DGPS. The images are cheaper and processed more simply and conveniently than higher ones. But surveying and post-processing by DGPS is more complicatedly.

Scheme3-Having Current High Resolution Images and History Middle Resolution Images: Higher resolution images must be otho-rectified firstly. Middle resolution images are rectified referencing to the higher one. Secondly, the two matched images are merged together. Change information will

be detected and extracted automatically with the algorithm of feature variance. An obvious shortcoming of this scheme is that the missed change spots should be more than those detected with scheme one. So, DGPS will be used on the fields to survey the missed change data. The advantage of this scheme is that change information can be extracted by computer automatically.

Scheme4-Having Current Middle Resolution Images and History High Resolution Images: The order of rectifying these two kinds of images is the same with that of scheme 3. The two images will be merged together. Change information will be detected automatically with the method of feature variance. But the shortcoming is that the extracted data can not satisfy with the accuracy need of scale 1:10000 land use maps. Because current year images have lower resolution, DGPS technology will be used on the fields to obtain the spots border points' coordinate with better precision.

Scheme5-Having Current High Resolution Images Only: Land use maps will be gathered as history reference materials in this scheme. In order to improve matching precision between land use maps and images, maps must be rectified firstly and images will be rectified referencing to these maps. Change area will be extracted by overlaying these two kinds of data together. With this scheme, the problem is that change information is extracted not so completely. DGPS can make up this shortcoming. The most advantage of this scheme is consume-saving.

2.2 Investigation on the Fields with GPS

Although most of land use change information have been detected with GIS and RS technology, but there is still some information which has not been identified or their precision can not reach the accuracy demand. The other problem is that it is difficult to make certain about each land use class right or not even assisted by other reference materials in doors. So, surveying on the fields with GPS is a very necessary work.

Generally, tasks of land use investigation on the fields are to check and collect information about each spot's attributes which include whether the building is new or not, which administrative attachment it belongs to, and the reason about infield land change, and etc.

Land use change detected with RS and GIS can be defined into two types: certain spots and uncertain spots. Both certain spots and uncertain spots are defined into two kinds as well: one comes from high resolution image and one comes from middle resolution image respectively. Different surveying methods aided by GPS will be selected for different kinds of spots. Those are navigation GPS and DGPS.

2.2.1 Investigation by Navigation GPS: Uncertain spots detected from high resolution image have good geometric accuracy enough to reach the precision need of mapping. But the category identification precision is not so satisfied. Change spots layer and images or land use maps are put into notebook PC or PDA which connected with navigation GPS. GPS provides current point position and directs people adjust his direction to the object place. This method can prevent people from losing his way and make investigation job more efficient and convenient.

2.2.2 Investigation by DGPS: Change spots which have lower geometric precision or have not been extracted by RS images

must be surveyed with DGPS technology. Hard ware system should include more than two sets of GPS. One is used as base station, the others as moving reference stations. The post-processing accuracy can be reach less than 1m.

2.2.3 Coordinate System Exchange: Each country has its suitable geodetic datum which includes ellipsoid, geodetic coordinate system and altitude datum. Because coordinates obtained by GPS are based on WGS 84 system, while our country's coordinate system is 1954 Beijing or 1980 Xi'an, it is necessary to exchange them from one to the other in order to make images matched by the coordinates well.

2.3. Updating

Data collected from investigation on the fields are put into land use GIS and overlayed with history LUDRG (Land Use Digital Raster Graph) or land use database. Change area between these two kinds of data is very clearly. Data is edited firstly, and then the attributes will be modified by input new information into the attribute tables. Some spot attribute of land use class before, land use class current, and the area can be obtained automatically by GIS software. The other change information should be input manually. After all of the data have been updated and checked, statistic works start up. With land use GIS software, all of the statistic and collect reports can be finished automatically.

3. EXPERIMENT

Jinnan county was selected as an experiment area. There are several questions to be answered during this experiment. First of all is how to select the most suitable images, the second one is how to extract change information and how well its precision can reach, the last one is how to use GPS surveying on the fields.

3.1 Experiment Area Introduction

Jinnan was selected as an experiment county representing north of Chinese county, which lies in north of Tianjin city. Its major physiognomy feature is plane. The main land use category is infield and breed aquatics besides resident.

Figure 1. Jinnan county image (Spot 10m + TM 30m)

3.2 Data Resources

Many kinds of data were used in this experiment. They were remote sensing images, topographic maps, land use maps, and DEM.

3.2.1 Remote Sensing Images:

Type	Number	Phase	Resolution	Bands
TM	1Scene	2001/09/01	30m	TM1, 2, 3, 4, 5, 7
SPOT4	1Scene	2002/10, 2003/10	10m	panchromatic
	1Scene	2002/10, 2003/10		
SPOT5	1Scene	2002/10 2003/11	10m 2.5m	multi-spectral panchromatic
Arial photos	16sheets	2003/1	1m	RGB color

Table 3. RS Images Used in Jinnan Experiment

3.2.2 Maps:
1:10000 topographic maps: 192 sheets used to rectify SPOT5 (2.5m) images

1:50000 topographic maps: 32 sheets used to rectify SPOT4 (10m) images

1:10000 land use maps: 28 sheets used to change detection and map updating

3.2.3 Dem:
1:50000: 32 sheets used to otho-rectify SPOT5 (2.5m) images

1:250000: 32 sheets used to otho-rectify SPOT4 (10m) images

3.3 Experiment Content

(1) Using middle resolution images (30m landsat7 and 10m SPOT4) to update land use maps made in several years ago. (2) Using high resolution images (SPOT5 2.5m and 1m aerial photos) to update old land use map.

3.4 Result

It is no meaning to statistic interpretation precision, because the precision of change spots area and their border points' coordination is not satisfied with the demands of 1:10000 map scale accuracy extracted by middle resolution images (30m landsat7 and 10m SPOT4), and other assistant materials to help us judging more detailed change information could not be gathered, many change spots during past years can not be detected and extracted. So, the test of land use investigation with two phases of middle resolution images is failing.

Investigation with one phase of high resolution images and other phase of middle resolution images was this experiment's emphases. From this experiment, some conclusion was obtained.

3.4.1 Extraction accuracy of Land use Category: Eleven categories of land use were extracted by interpreting from SPOT5 (2.5m) and checked by navigation GPS out of the door. We found that orchard, water, river and beach can be extracted correctly. But forest and waster land were identified not so good. The reason is that waster land is very easy to be confused with breed-pond, and forest is easy to be confused with weed by not only computer but also human interpretation since they have the similar spectral characteristic in images.

We compared the spots category identified by RS images in doors with its real category investigated at the real place, and got the extraction accuracy of several typical land use category which is shown at the following table.

Land Use Category	Identified in Doors		Right Percent (100%)
	Wrong number	Right number	
Infield	5	34	89.74
Orchard	0	62	100
Forest	10	15	60
Water	0	88	100
Town	2	2	100
Village	5	83	92
Factory	1	20	91
Road	1	4	100
Waster Land	1	3	75
River	0	2	100
Beach	0	8	100

Table 4 Land use Category Extraction Accuracy

3.4.2 Border Points' Coordinate Precision: Change spots' border was surveyed with GPS. Compared to GPS data, the least RMS of spots border of images is 7.44m, and the biggest RMS of spots border is 9.86m. That is according with the need of scale 1:10000 maps.

Spots Index	GPSX(m)	GPSY(m)	imageX(m)	imageY(m)	X	Y	error(m)
121	4318781	39535767	4318786	39535768	-5	-1	5.10
	4318564	39535887	4318562	39535888	2	-1	2.24
	4318644	39535100	4318647	39535100	-3	0	3.00
	4318838	39535275	4318823	39535290	15	-15	21.21
	4318947	39535223	4318952	39535230	-5	-7	8.60
	4318798	39535791	4318802	39535793	-4	-2	4.47
	RMS(m)						7.44
125	4318655	39535529	4318661	39535526	-6	3	6.71
	4318767	39535731	4318773	39535740	-6	-9	10.82
	4318578	39535806	4318580	39535818	-2	-12	12.17
	4318474	39535597	4318479	39535589	-5	8	9.43
	RMS(m)						9.78
115	4318725	39538905	4318728	39538897	-3	8	8.54
	4318872	39538879	4318882	39538879	-10	0	10.00
	4318941	39539165	4318951	39539163	-10	2	10.20
	4318909	39539170	4318900	39539172	9	-2	9.22
	4318874	39539091	4318885	39539091	-11	0	11.00
	4318736	39539095	4318746	39539093	-10	2	10.20
	RMS(m)						9.86

Table 5 Border Points' Coordinate Precision

3.4.3 Area Precision: Area precision is one of the important values for land use spots. Spots were selected to statistic their accuracy which categories and figures in images is similar to the reality. Area between data measured from images and from field surveyed was compared. The result is listed below:

Spots ID	Surveyed by GPS (m^2)	Measured by RS (m^2)	Difference (m^2)	Error percent (100%)
121	96356.39	93971.37	2385.02	2.84
115	35053.58	36681.83	-1628.25	4.65
123	57626.18	67703.39	-10077.2	17.49
125	46698.9	51769.26	-5070.36	10.86
139	23869.25	22547.79	1321.46	5.54
151	70330.15	83657.52	-13327.4	18.95
156	49675.68	52395.95	-2720.27	5.48
160	9307.02	8153.74	1153.28	12.39
159	21540.98	18800.94	2740.04	12.72
195	67559.25	36368.49	53185	78.72

Table 6. Area Precision

From the above table, the largest difference spots are No.195. Because the area has been still changed after the images obtained.

4. SOFTWARE

A series of software facing to land use investigation (especially suitable to our country) has been developed. Most of land use investigation function is designed in this software according to considering our country's investigation characteristic. It is divided in several models which include image otho-rectification, multi-resource images matching and merging, change information extracting and statistic automatically, surveying with GPS, map updating, and etc. With this series of software, data formats and standard can be unified. Computer solves many problems more rapidly and correctly which has been embarrassed land use investigation workers for many years.

5. CONCLUSION

Four kinds of Chinese counties have been classified according to their land use characteristic, economical development, area, the speed of land use change, and etc. Which kinds of remote sensing images are the most suitable for some county land use investigation can be looked up from table1.

There are five schemes about change spots extraction and surveying with GPS recommended for different county according to which kind of images and materials they are in possession of.

From the experiment in Jinnan county of Tianjin, we can conclude that using high resolution images (for example, SPOT5 2.5m) this year and the other reference materials(land use maps or land use database) last year can extract the change information for 1:10000 map scale geometric need. Navigation GPS can guide people to the object place and ascertain land use category.

In a word, modern technology of "3S" is feasible and efficient for land use investigation, especially at this time that the high resolution remote sensing images can be obtained and processed easily. It will accelerate the speed about improving modern management of land use. Computers and GPS will substitute for human's hands, feet and eyes. Although change information can not be detected and extracted completely automatically, but with the aids of modern technology and software, the speed of interpretation will be accelerated, too.

6. REFERENCES

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