AGRICULTURAL LAND INVESTIGATION AND CHANGE DETECTION BY INCORPORATING GIS AND SATELLITE REMOTE SENSING: CASE STUDIES IN SICHUAN PROVINCE, CHINA

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ABSTRACT

Repeat agricultural land information requirements prompt the study of the potential application of remote sensing techniques and geographical information system (GIS). A procedure for agricultural land investigation and change monitoring by incorporating these techniques was summed up through the studies carried out recent years in Sichuan province, China, which was proved feasible and operational. This paper also discussed thoroughly two case studies adopting the procedure. In addition, some further research aspects were pointed out which should be in consideration to make the sort of procedures more operational and more efficient.

1. INTRODUCTION

The needs for reliable, precise and up-to-date information on agricultural land and its change are growing, since there exist heavy demands from government ministries such as the Ministry of Agriculture, the National Bureau of Land Management, and diversities of regional and local government authorities. This is also true even for some non-departmental organizations, such as the Commission for Construction. The present, annually available information is mainly sourced from multipurpose statistical data, which do not meet the specific requirements on agricultural land information often because of inadequacy of type of data, time and relative precision.

For satisfying these needs, series of projects have been carried out since 1986, based on diversities of original data and some specific requirements of information, such as those on peat resource (Yu et al 1992), desertization, land use, soil erosion, and forest. This paper describes a feasible, operational procedure for agricultural land mapping and change detection on a large scale by using Landsat Thematic Mapper (TM) image or other high resolution satellite images. Two case studies are presented to show the carrying-out and the results of the approach.

2. OPERATIONAL PROCEDURE

In correspondence with the constant requirements of timely information, series of projects have been carried out nationwide. The following summarized the basic requirements of these projects.

a. The information achieved on agricultural land and its change should be representative on a large scale, to be useful for national or provincial decision making.

b. Both time and accuracy is important concerns. It is not acceptable that the investigation is highly accurate but too time-consuming, or instant but unreliable results.

c. The information should be obtained within a reasonable cost. Normally, there is no sufficient budget to support the carrying-out of aerial photography or the acquirement of digital satellite image in these projects.

d. Change detection is a long-range and repeat task. Investigation will be repeated on the same area and for the same purpose. Information will be renewed annually.

Therefore, the procedure used by the project is mainly based on the visual interpretation of Landsat TM image in print with preprocessing and geometric correction, completed in the light of the available historical data and the routine ground survey. This may be the cheapest and quickest way to fulfil these tasks in a developing country. See Fig. 1.

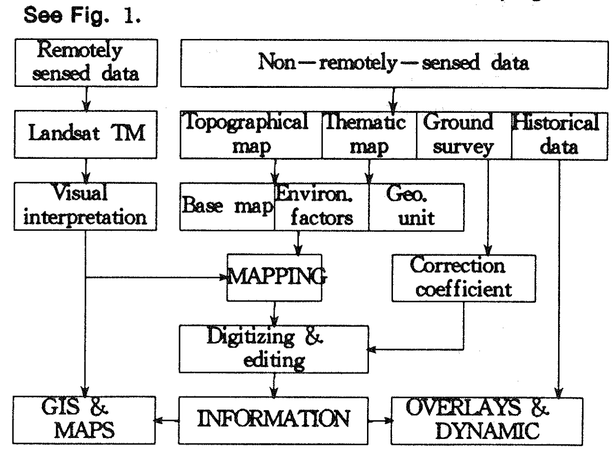


Figure 1. Flow Chart of the Agricultural Land Change Monitoring

Geographical information system is used to manage all the data and the information with facilities to fulfil editing, area summary, interactive information retrieving, and updating.

3. CASE STUDIES

3.1 Cultivated Land and Plantation Change

There has been a decrease in agricultural land and paddy field, due to urbanization, routine construction, and shifting of use since the Reform and Open Policy of 1979. In response to the need for the consistent, reliable information supporting the macroeconomical policy-making and furthering the reform and development of Chinese economy, the Ministry of Agriculture initiated the project, Dynamical Remote Sensing Survey of Cultivated Land and Plantation Change (DRSS), in 1992.

The study area was determined both by the requirements of the nationwide program on the same purpose and the representativity of cultivated land, paddy field, and their change. Therefore, the study area is at the central part of the Purple Basin, Sichuan province, China, between E103 °-107 ° and N29 °-31 °, covering an area of about 35,000 square kilometres, which is one of the most productive areas, especially rice.

The DRSS project was designed to obtain information using Landsat TM images of separate dates: 1992, the current distribution of features; 1991, the look-back. Another set of information for comparison is the results of the First National Inventory of Land Use carried through in the early 1980s, which represent the status in 1981/1982. The investigation will be repeated annually. To guarantee the availability of data, a much bigger study area was used, in case there is a need for shifting arising from the covering of clouds or other reason.

The classification system includes seven categories at first level and seven subcategories at second level. See Table 1.

First Level		Second Level	
Code	Name	Code	Name
1	Cultivated Land	11	Paddy field
2	Settlements and Township	21	City and township
		22	Rural settlements
3	Communication	31	Railway
		32	Highway
		33	Civil airport
4	Development Zone		
5	Isolated mills and mines		
6	Irrigation and Hydro-works		
7	Other		

Table 1. Land Use Classification System

The minimum polygon is greater than or equal to four square millimetres on the map of 1:100,000, i.e. 4 hectares on ground, and the minimum width of linear targets required is greater than or equal to 10 metres on ground.

The width of linear targets and dispersed isolated rural settlements is not obtainable on the Landsat TM image and will be learned from ground survey, large scale airphotos, and available data. For linear targets, different methods are used in accord with the subcategories. Width of railways is definitive on single or double lined routine. Highways are roughly classified to three levels and the width at each level is almost the same. These will be figured out from available documents. Paths and ridges cannot be seen on the satellite image, but they do take up a large portion in the mapped cultivated land and should be subtracted from the cultivated land. Enough samples selected within a stratified random sampling design in which strata are defined with landform are investigated to find out the compensation coefficients. Although this is laborious, the coefficients are obtained, fortunately, mainly from the available results of the recent nationwide land use investigation on the scale of 1:10,000 in lowland and 1:50,000 in highland. For rural settlements, there are many tiny spots visible on the TM image but not considerable in mapping. A similar method to that of paths is adopted to make compensation for the incomplete of the information. The number of 'spots' are counted on enlarged Landsat TM image or airphotos and the area data are achieved by multiplying an average area of individual rural house or homestead. Generally the area of each homestead mainly differs on various type of landform that decided the construction. Therefore, the strata for samples are defined in the light of landscape regionalization.

Once the compilation for area features had been drawn and checked both on a map and on a sampled field, the boundaries were digitized, edited, and topologically built using ARC/INFO geographical information system. A statistical software with the direct access of the dBASE formatted data specifically developed for the project was used to sum up the area data incorporating the coefficients and the width of the linear targets.

Figure 2 shows the diversities of land change ratio over different counties. Urbanization results in the decrease of paddy field and dry cultivated land. This is also obvious in Figure 3. It was resulted that the change ratios, to some extent, depend on the national policy and there exist terrestrial discrepancies (Zen et al 1994).

3.2 Resources and Environment Monitoring

Inventory and monitoring of resources and environmental background is heavily demanded for regional development, especially for the development of the west part of Sichuan province which covers over the half of the provincial land. There, the diversity of landscape with steep valley and high mountain makes the inventory and monitoring more difficult and inaccessible. Remote sensing technique seems an ideal tool for this purpose. Therefore, the Resource and Environment Monitoring (REM) was carried out nationwide as the key project of the Eighth-Five Year Plan by a cooperative team consisting of members from the Ministry of Agriculture and Chinese Academy of Sciences, which will be completed in this year.

The main goal of REM is to define clearly the area statistics of renewable resources and land, especially cultivated land, built-up area, forest, pasture, unused land, and the environmental variations, including such factors as temperature, humidity, landscape. The transferring of the sophisticated technology of remote sensing to local administrative agencies is an adjunct to the main objective. The results will be managed by a sophisticated and specific GIS, with friendly interface, to be easily handled by local administrators and planners. Mapping scale is 1:250,000 for agriculture-intensive area and 1: 500, 000 for remote and sparsely settled area.

A standard classification system is used to enable the comparison and the coherence of information resulted. A code system specific for the project was standardized to save storage space and handle information conveniently on the same criteria. The Table 2 shows the classification system.

First Level		Second Level	
Code	Name	Code	Name
1	Cultivated Land	11	Paddy field
		12	Dry land
2	Forest Land	21	Forest
		22	Shrubs
		23	Other
3	Grassland	31	Grassland with high coverage
		32	Grassland with moderate coverage
		33	Grassland with low coverage
4	Water	41	Rivers and canals
		42	Lake
		43	Reservoir and pond
		44	Glacier and permanent snow
		45	Tided coast
		46	Floodplain
5	City, township, mills, mines, and settlements	51	City and township
		52	Mills and mines
		53	Other
6	Unused Land	61	Dunes
		62	Gobi
		63	Saline and alkaline land
		64	Swamp
		65	Bared soil
		66	Bare rock and gravel
		67	other

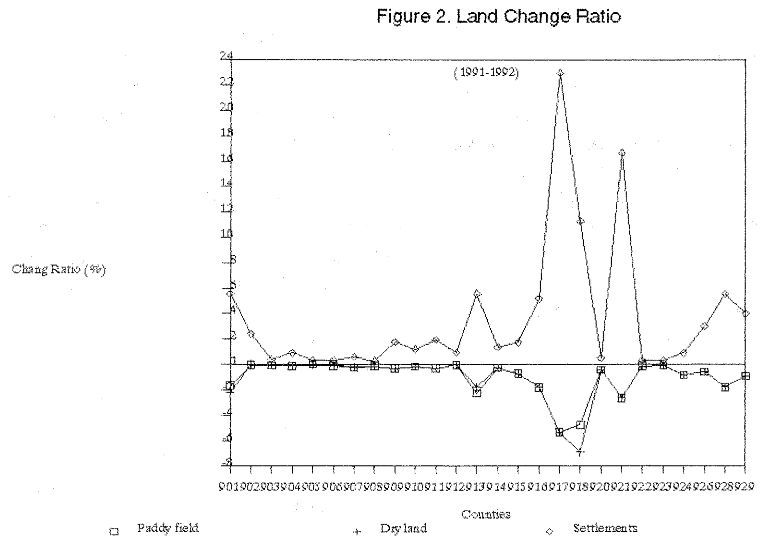
Table 2. The Classification System for Resources

A similar procedure to that for the DRSS project is used in the REM project, but more sophisticated on the items considered compensated. All the subcategories at second level are compared cross-linkedly based on the information extracted on some high resolution photos taken by the sensors of satellite Pioneer 1 of China, which find back the lost information up to the accuracy achieved on the scale of about 1:100,000.

To assign the value of environmental background more efficiently to each basic polygon that represents the minimum geographical unit with homogeneous attributes of environmental features, the basic polygon, or geographical unit, is derived from the overlay analysis of each environmental factor, including temperature, humidity, surface material, and terrain feature. The categories are shown in Table 3. This enables the advantageous use of the-art-of-the-state techniques simplified by any well-developed geographical information system.

Temperature		Relative humidity		Surface material		Terrain feature	
Code	Type	Code	Type	Code	Type	Code	Type
1	Tropical	1	Sultry	a	Clay	A	Mountain
2	Sub-tropical	2	Sub-sultry	b	Loam	A1	Extremely dissected
3	Warm and hot	3	Sub-arid	c	Silt	A2	Deeply dissected
4	Temperate and hot	4	Arid	d	Gravel	A3	Moderately dissected
5	Temperate and warm	5	Extreme arid	e	Rock	A4	Slightly dissected
6	Temperate and cool					A5	Karst
7	Temperate and chill					B	Hills
8	Chilly					B1	Loss hill
9	Frigid					B2	High hill
						B3	Mid. hill
						B4	Low hill
						B5	Karst hill
						B6	Sand dunes
						C	Terrace
						C1	High
						C2	Moderate
						C3	Low
						D	Plain
						D1	Undulated
						D2	Slant
						D3	Flat
						D4	Lowland
						D5	Upland

Table 3. Types of Environmental Factors



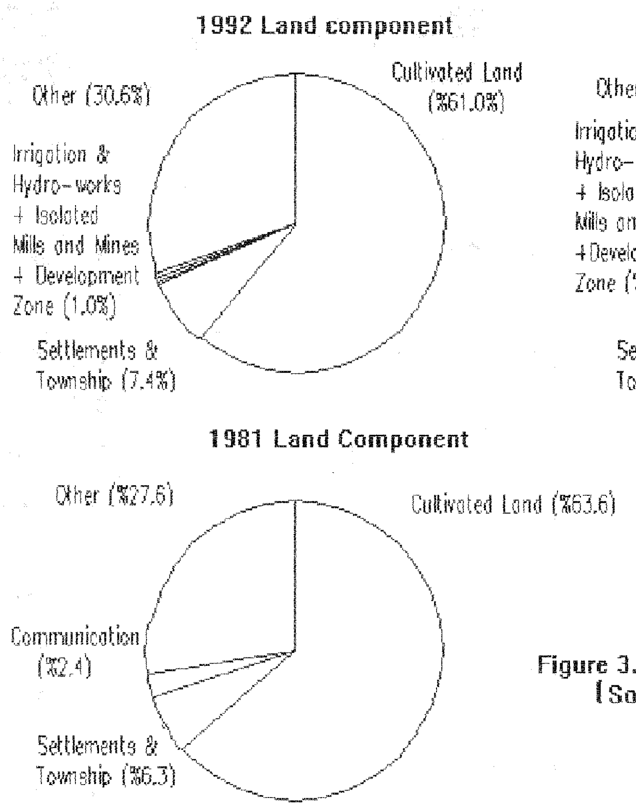


Figure 3. Land Change in Sichuan Basin, China (Source: 1991 & 1992 derived from TM image 1981 derived from MSS image & statistical data.)

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As a subsidiary of using GIS, querying and updating of information stored could be easily maintained. A specific system for the distribution of the results of the project was designed and has been revised with a Chinese interface.

4. FURTHER STUDY

Following on from the DRSS study the Ministry of Agriculture initiated the Monitoring Agricultural Land (MAL) project in southwest China, a more comprehensive study on the potential use of satellite data for agricultural statistics. The MAL project aims at the acquisition of agricultural information with high-speed, sophistication, up-to-date facts, and dynamics. Further study would be focused on the reduction of cost concerning time, money and labour, including trial studies on operational or sub-operational procedures by adopting sampling techniques and incorporating computer aided image recognition with expert knowledge.

5. CONCLUSIONS

The 'routine survey + GIS + remote sensing' procedure by using satellite image has been proved to be successful in the monitoring of agricultural resources on the middle scale of mapping in China. The GIS enables the full operational management of data and information with the advantages of easy-handling and easy-updating.

Further research effort over the next few years will enable a comprehensive and efficient methodology, as for both accuracy and cost, to be devised. Such a methodology will enable a repeat agricultural land monitoring by thoroughgoingly using the potential of satellite remotely-sensed data to produce information on a full range of crops, with the precision demanded by the administrators and planners who require access to the information.

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